Water Power
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER
FEBRUARY 1952

THE JOHN CRERAR
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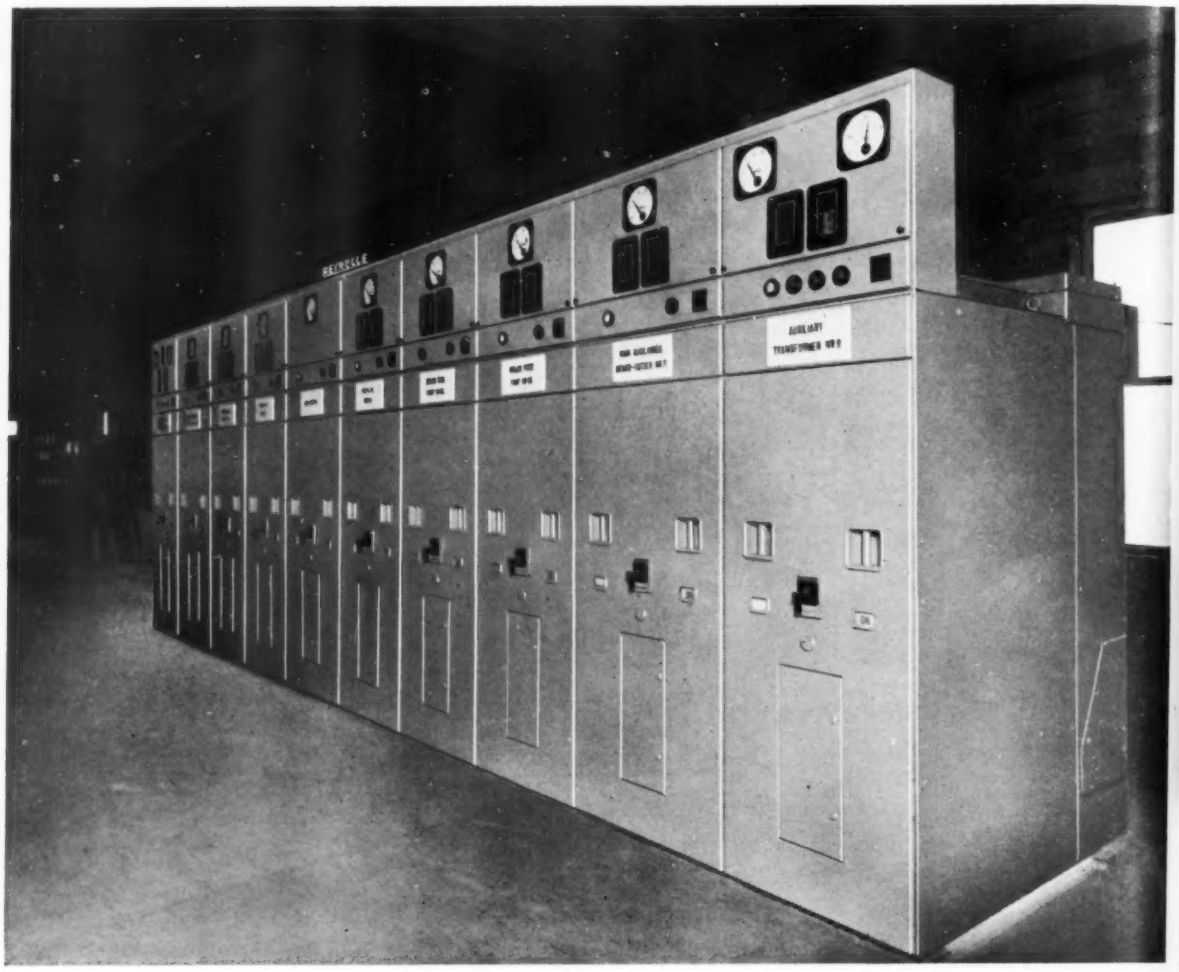
hydro-electric equipment

Complete hydro-electric generating plant manufactured by 'ENGLISH ELECTRIC' is supplying power to industry and to homes throughout the world.

Illustrated is Pollaphuca Power Station, Eire.

The ENGLISH ELECTRIC Company Limited, Queens House, Kingsway, London, W.C.2
Hydro-electric Department, Stafford
Works: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL



AIR-BREAK SWITCHGEAR AT CLYDESMILL

At Clydesmill Power Station, Reyrolle 150 MVA 3·3 kV air-break switchgear has been installed for controlling the power station auxiliaries. The panels are of air-insulated metal-enclosed construction with 150 MVA magnet-operated circuit-breakers. The circuit-breakers are isolated for maintenance and inspection on integral carriages and as they have easily removable arc-chutes, the whole contact assembly is readily examined. Particular care has been taken in designing the exterior and the result has been panels of neat and clean appearance.

If you want to talk switchgear ... talk to Reyrolle

A. Reyrolle & Company Ltd., Hebburn, Co. Durham.

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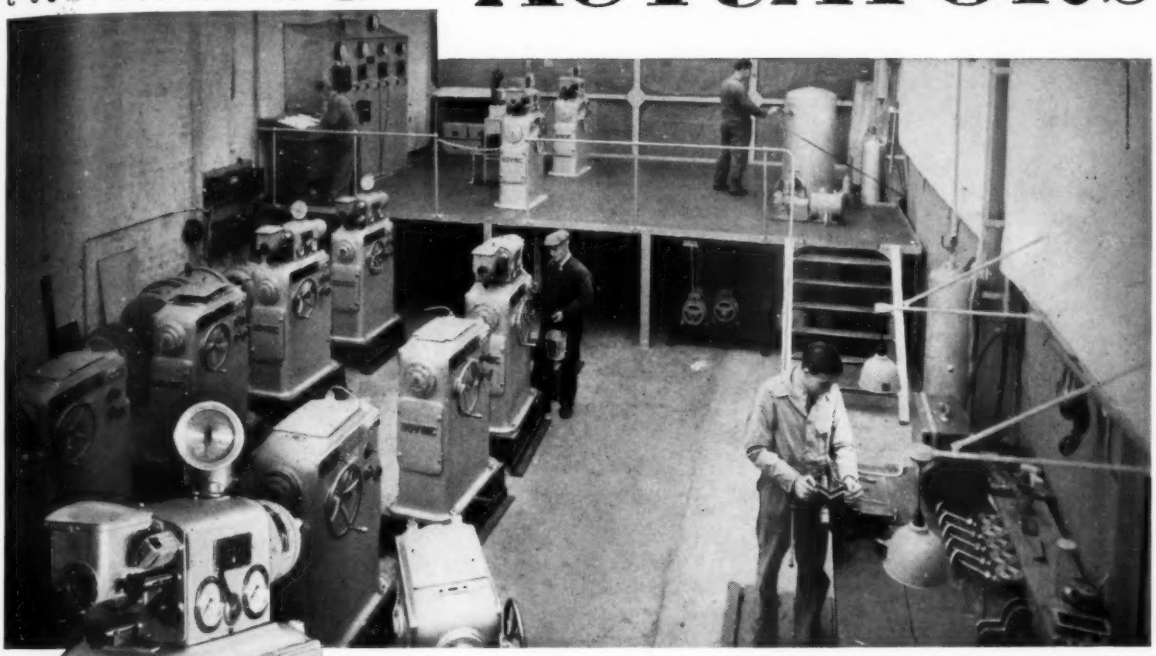
WATER TURBINE ACTUATORS



This is the most modern type of Boving Actuator — the F.10 and it is here seen both in process of assembly, and undergoing test at the works of John Brown & Co. Ltd. at Clydebank.

These Actuators contain the speed-responsive element of the governing system of large water turbines. They are highly sensitive and embody every modern feature to enable them to meet the onerous governing requirements of a large turbine.

In normal practice Actuators are arranged for remote control and the F.10 is particularly suitable for fully automatic plants.

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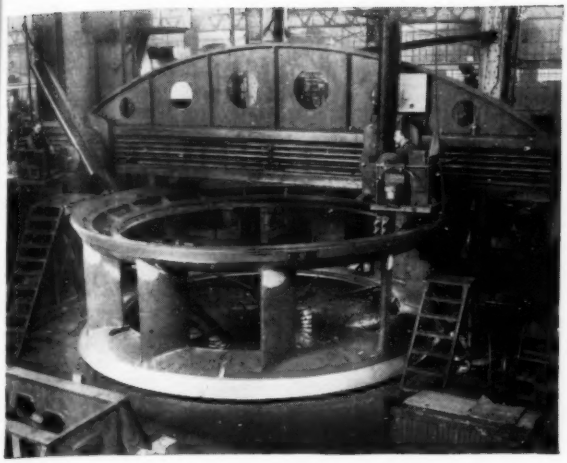

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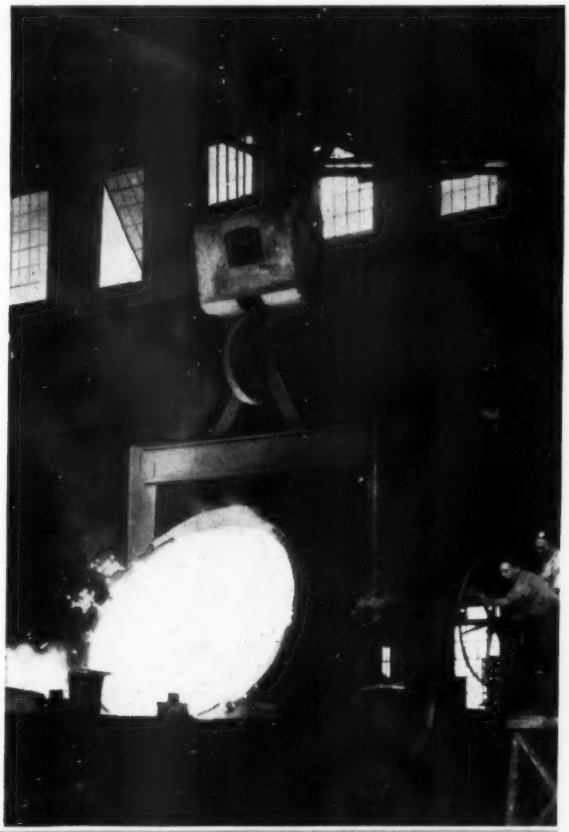
Write to P.O. Box 220, Montreal, for Hydraulic Turbines Bulletin No. 201.



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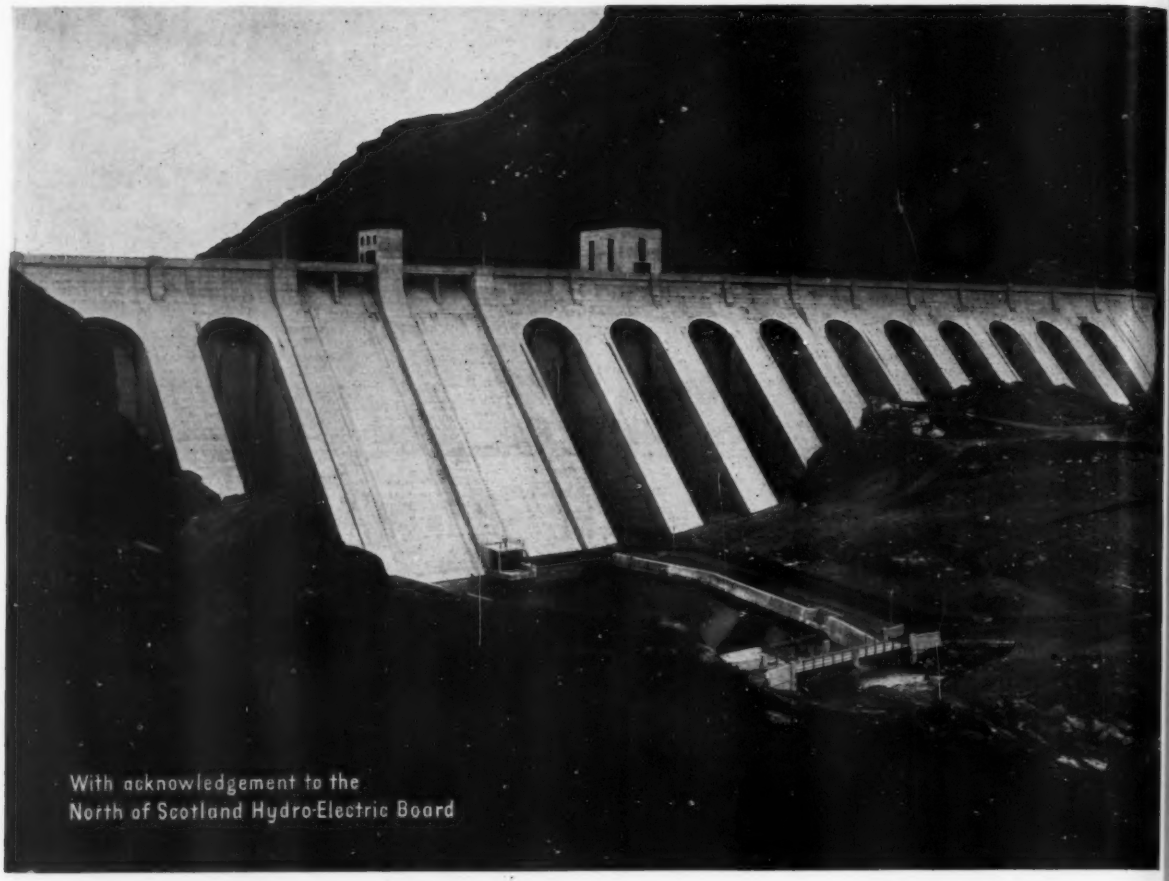

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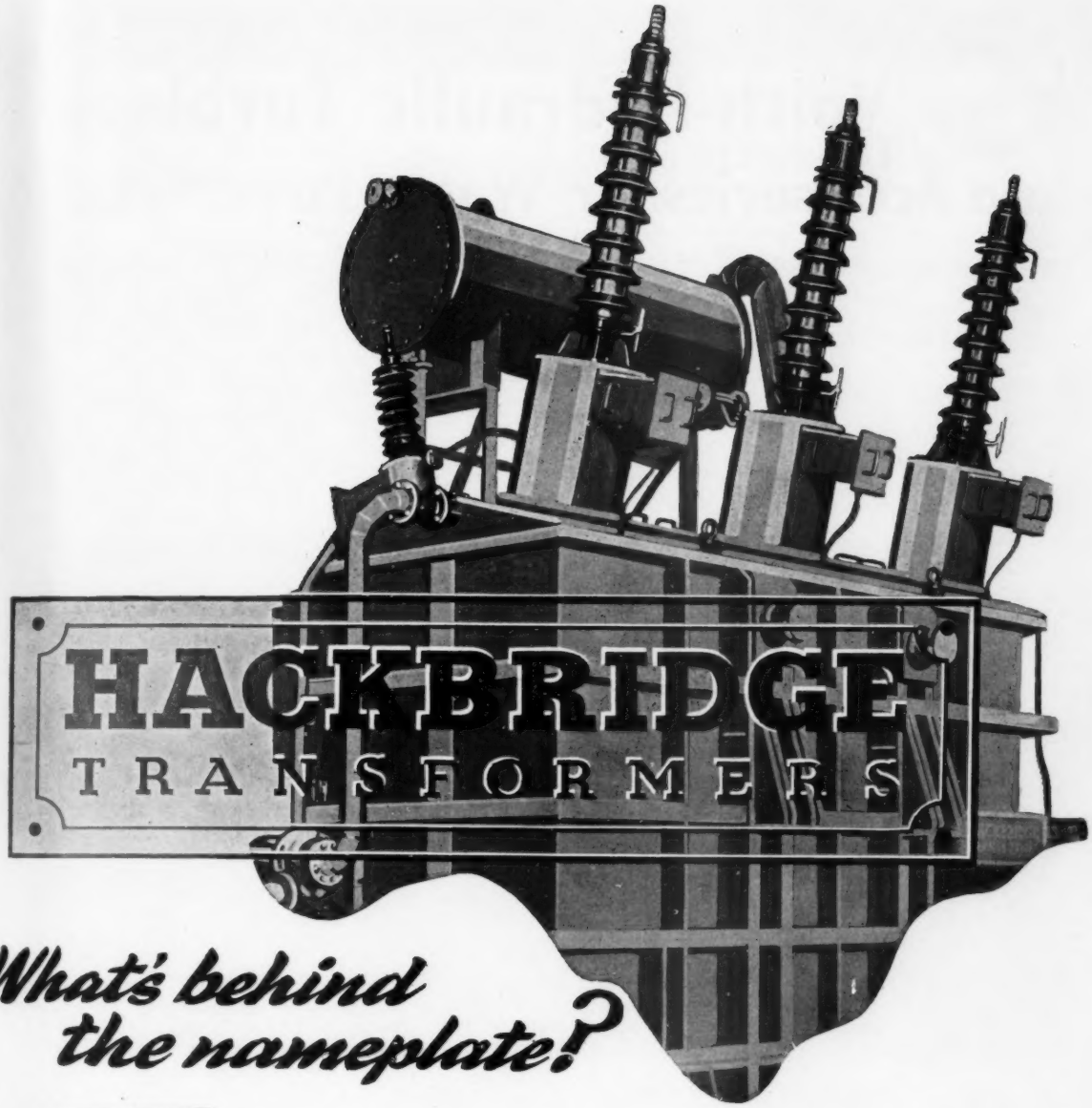

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TWENTY-FIVE years experience in design and manufacture and an output of **seventeen million kVA** of transformers, in all types and sizes, including some of the world's largest. Such figures are a true measure of excellence, for they could have been achieved only by the maintenance of the highest standard in design and construction and on a basis of long and reliable service.

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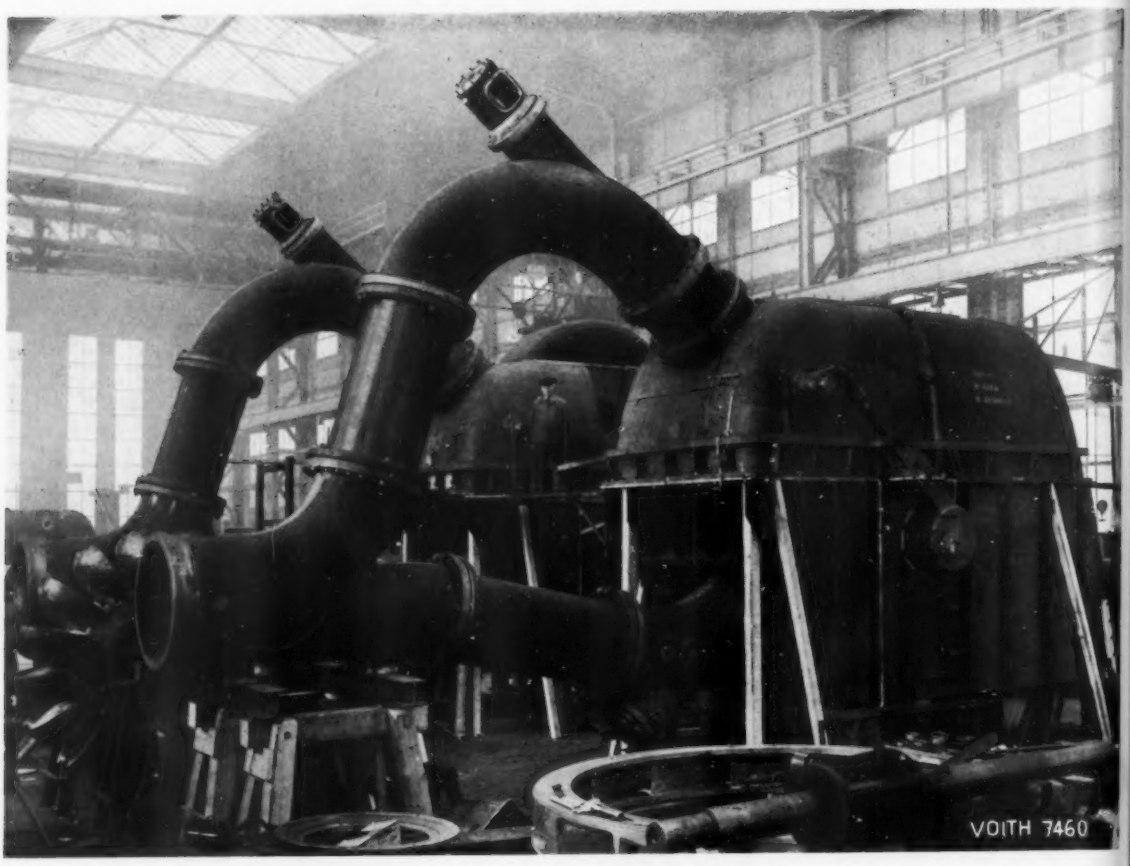

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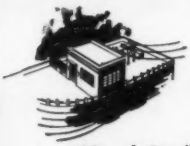


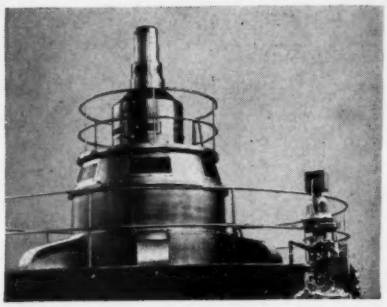
The lonesomest plant in Puerto Rico

Although Caonillas No. 1 is a busy plant—producing up to 22,000 kva and running full blast—you seldom see a man in it. Completely automatic operation makes it the lonesomest plant in Puerto Rico.

There's not even a man around to check on operation. That's done by remote control 10 miles away at Dos Bocas power plant—nerve center for three stations of the Caonillas Hydro-electric Project which supplies power to all points in Puerto Rico. At Dos Bocas, operators can tell by a glance at the Westinghouse control panel what is happening at Caonillas No. 1.

Sixteen billion gallons of water for this station are stored behind a concrete dam built across Caonillas River. It's a straight gravity overflow type dam, 850 feet long at the crest, and 250 feet above river bed. A pressure tunnel conveys impounded water through solid rock to No. 1 power house 2½ miles downstream, where two Westinghouse vertical waterwheel generators produce inexpensive power for transmission to thriving San Juan, and for irrigation and standby service.

Caonillas project, conceived and built entirely by Puerto Rico Water Resources Authority under the general direction of Antonio Lucchetti, Executive Director, adds vital new output to the Authority's expanding electrical network. Working directly with Authority engineers, Westinghouse was able to apply broad technical knowledge and manufacturing skill in designing hydroelectric plants and remote control.



Two Westinghouse vertical waterwheel generators similar to this unit were installed at Caonillas—each 11,000 kva, 3-phase, 60-cycle, 4160 volts, 514 rpm. Westinghouse builds both vertical and horizontal types, in practically all frequencies, speeds and voltages. For further information on power generating and distributing apparatus write to Dept. Y.

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TARGET DA

Record tunnel driving performa

at the Volturno River hydro-ele

plant in Italy–thanks to the Swe

Method, adapted in this instance

a type of rock which created unu

drilling and blasting difficulties.

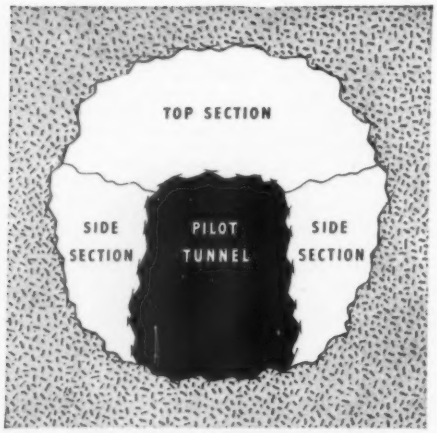

Fig 1 *A cross section of the Volturno tunnel (16 ft. 3 in. diam.) showing the rock face as divided into four areas for drilling and blasting.*

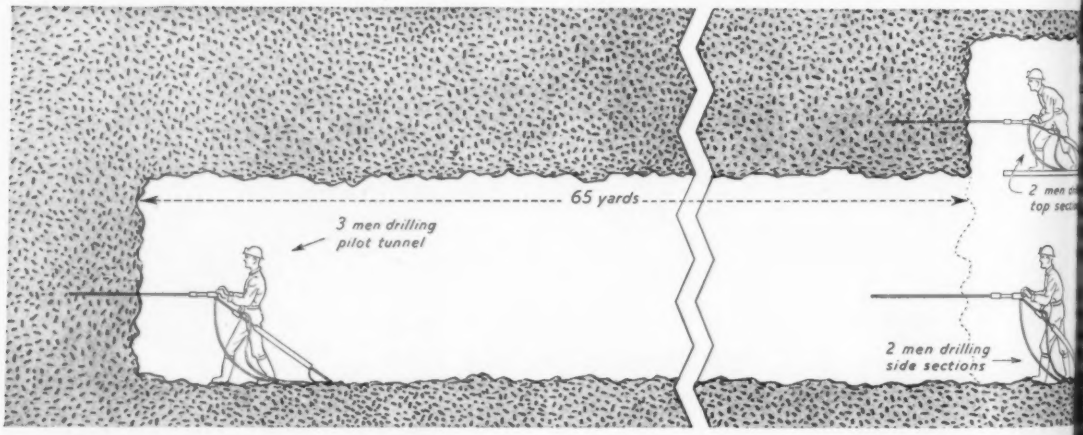

Fig 2 *The drilling operation, showing men at work on two headings with light Atlas Diesel Rock Dri with Sandvik Coromant Dri*

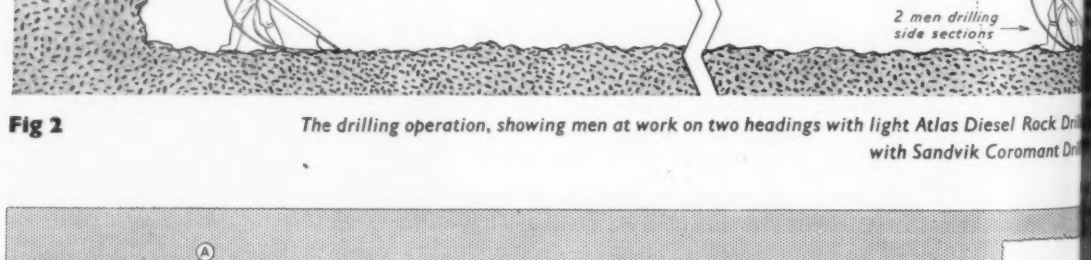

Fig 3 *Mucking-out took place in the main tunnel and the pilot tunnel simultaneously—an importan in time saving. A and B show compressed air driven loaders at work; C is the train of 15 cars into the pilot tunnel prior to blasting, and D indicates the niches cut in the side of the tunnel for cars to be side-tracked in order to load all 15 cars operating on a sing*

EATEN BY FIVE MONTHS!

ardly a week passes without some new story of exceptional tunnelling performance by what is now known all over the world as the Swedish Method. This one, from Italy, is ing in that it concerns a special adaptation of hod for the type of rock encountered.

e work was executed by the Contractors, A. Farsura of Milan, and the tunnel was de- to convey water from the Volturno River to a dro-electric plant now nearing completion at d'Evandro, Campobasso.* It was just over long, with a diameter, before lining, of 16 ft., e rock was compact limestone of extremely vari- aracter which called for special drilling and measures.

e drills used were light Atlas Diesel. type RH- with pneumatic pushers, fitted with Sandvik ant Drill Steels. The ease and simplicity with hese light drills are handled by one man in con- pace was largely responsible for the exception- pid progress. Another equally important factor ermining speed was, of course, the use of Sand- Coromant Drill Steels, which, in this type of rock, be used almost interminably without re-sharp- (Even in the toughest leptite a Sandvik Coro- Drill Steel will penetrate 50 feet before effectively gauge or edge).

Many drilling methods were discussed with the consultants, and after various tests the Chief er in charge of the work, Signor Arrigoni, de- on a division of the rock face into three drilling as shown in the accompanying diagram, with ot tunnel driven unusually far in advance of the eading. This was partly to allow for a more de- examination of the rock, and so adapt blasting ds in the main heading during progress, and to facilitate mucking-out. The length of the unnel enabled a whole train of 15 cars to be in before blasting the top and side sections of ain heading. In this way it was possible for ng-out to take place in the main tunnel and the unnel at the same time, the operation so timed e whole train of cars moved out together, mak- y for the two new gangs of drillers.

The rate of progress on the Volturno tunnel con- d a record for tunnels of this type. During 270 ng days 15,210 feet of tunnel were accomplished wo faces: during the week of 8-15th October e figure was 295 feet, and the highest figure for y (29th November) was 69 feet.

e original target date set for the completion of nel was 31st May 1951. The tunnel was actually d on 12th December 1950, *five months ahead of le!* This vital saving was only made possible by e of the Swedish Method.

power station, now under construction for the Meridionale di Elettricità, Naples, is designed annual production of 137,000,000 kWh.

AND YET ANOTHER...

BRITISH TUNNELLING RECORD BEATEN AT LOCH SLOY!

Yet another triumph for the Swedish Method—and this time the story comes from Scotland.

During the week ended Sunday, 10th June 1951 three gangs of ten men, using Atlas Rock Drills with pneumatic pushers and Sandvik Coromant Drill Steels and working 21 shifts of 8 hours each, drove 427 feet through hard diorite rock. How's that for productivity!

The tunnel is 7 ft. by 7 ft. and when completed will be 6,000 feet long. It forms a part of the North of Scotland Hydro-electric scheme, and the Contractors (to whom we are indebted for this picture of the team) are Edmund Nuttall, Sons & Co. (London) Ltd. This beats this company's previous record of 313 feet established three months earlier. Subject to confirmation, the figure of 427 feet is understood to be a new European tunnel driving record.

ture describing the Swedish Method with s of the equipment used may be obtained by g out this Voucher and posting it to the Atlas Company Ltd., attached to your business or sional letterheading.

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Please send us literature describing the Swedish Method, addressing it personally to:

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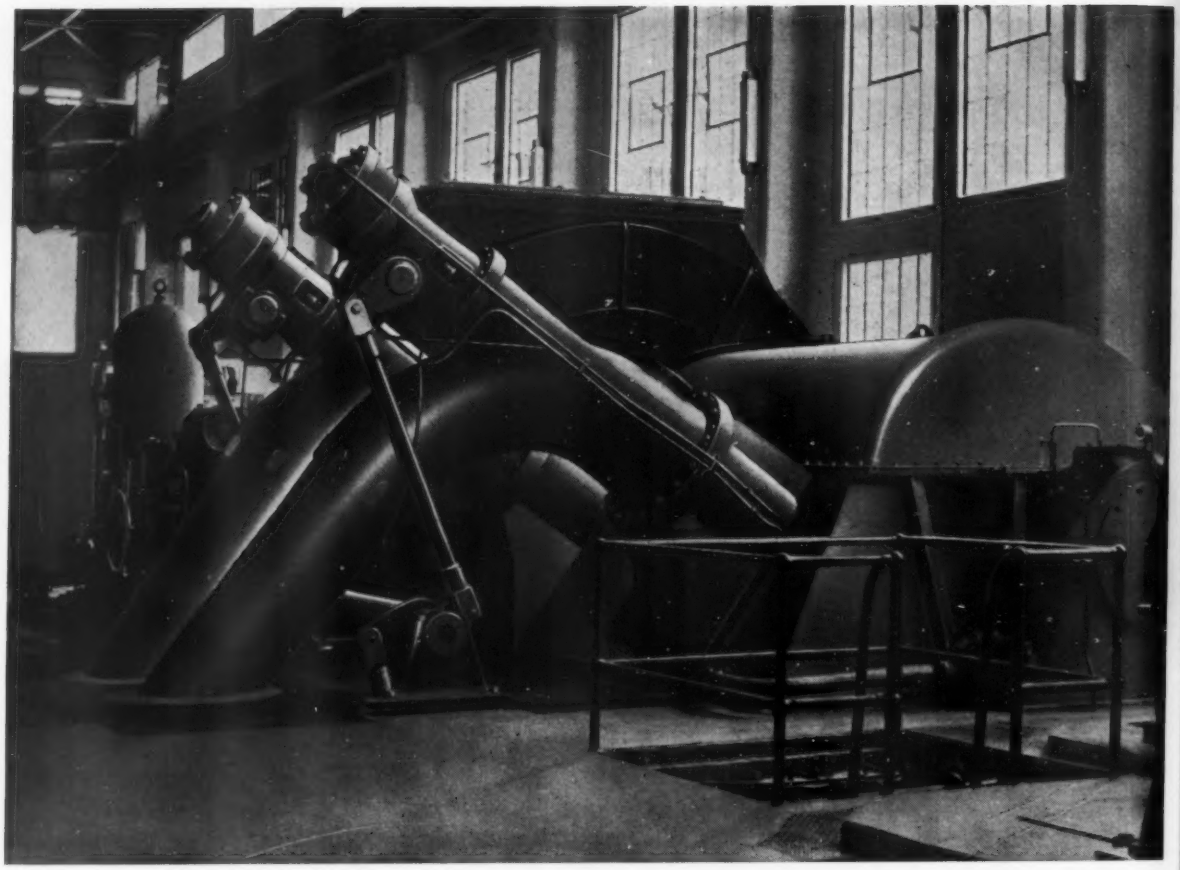

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'ENGLISH ELECTRIC' hydro-electric plant of all types and sizes has been installed in all parts of the world under widely diverse conditions.

The illustration shows the turbine end of one of the 21,000 h.p. double runner twin jet impulse water turbines. These operate under a 940 ft. head at 428 r.p.m., and drive 16,750 kVA 11,000 volts 50 cycles alternators at the Tarraleah Power Station in Tasmania.

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HE.4

Another job well done by Millars' Wellpoints

Discharge Culvert connecting the Main Flume with the Cofferdam going out to sea at the Carmarthen Bay Power Station. In this contract the water table has been successfully lowered from ground water level at 108 ft. to a depth of 74 ft.—sub grade being 76 ft.—by the use of Millars' Wellpoint Dewatering System. The top of the bank is 2 ft. above high tide; this is an excellent example of the efficiency of this equipment under difficult conditions and it can be seen from the photograph that the excavation is completely dry.

Write for further details to Dept. W.P.1

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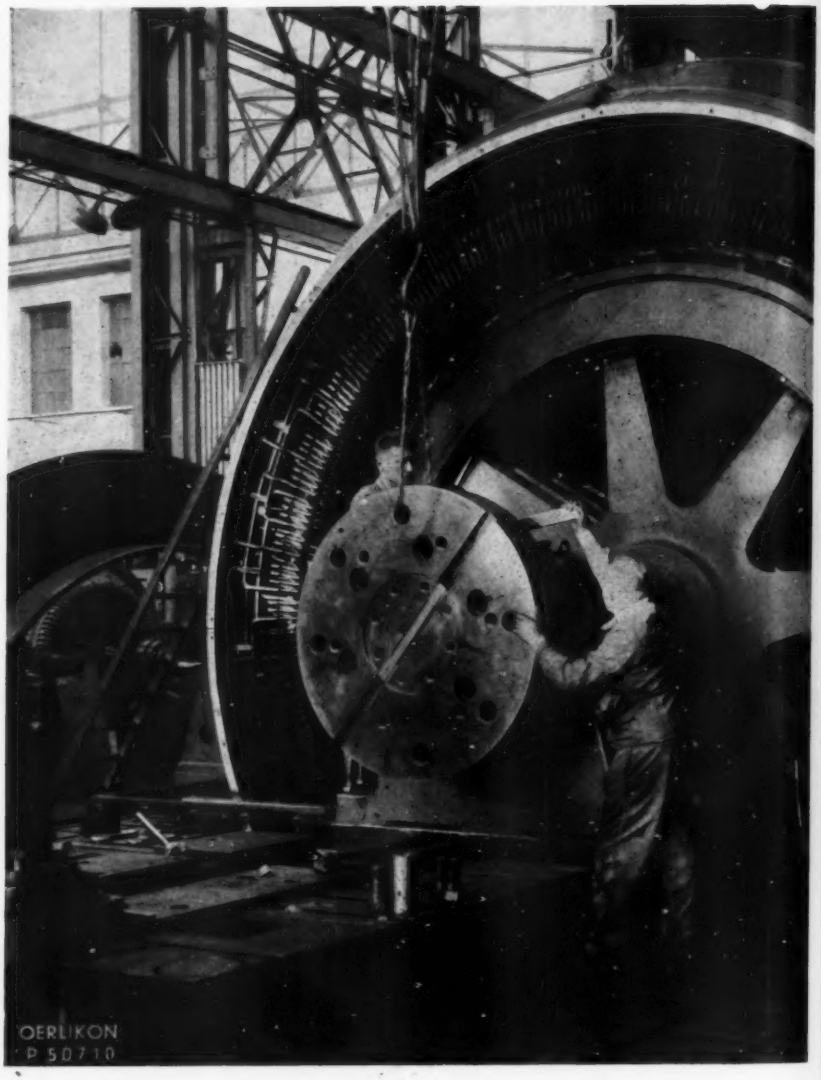

Assembly at the Oerlikon works of a horizontal generator of 17500 kVA for the A.S. Rjukanfos, Norway.

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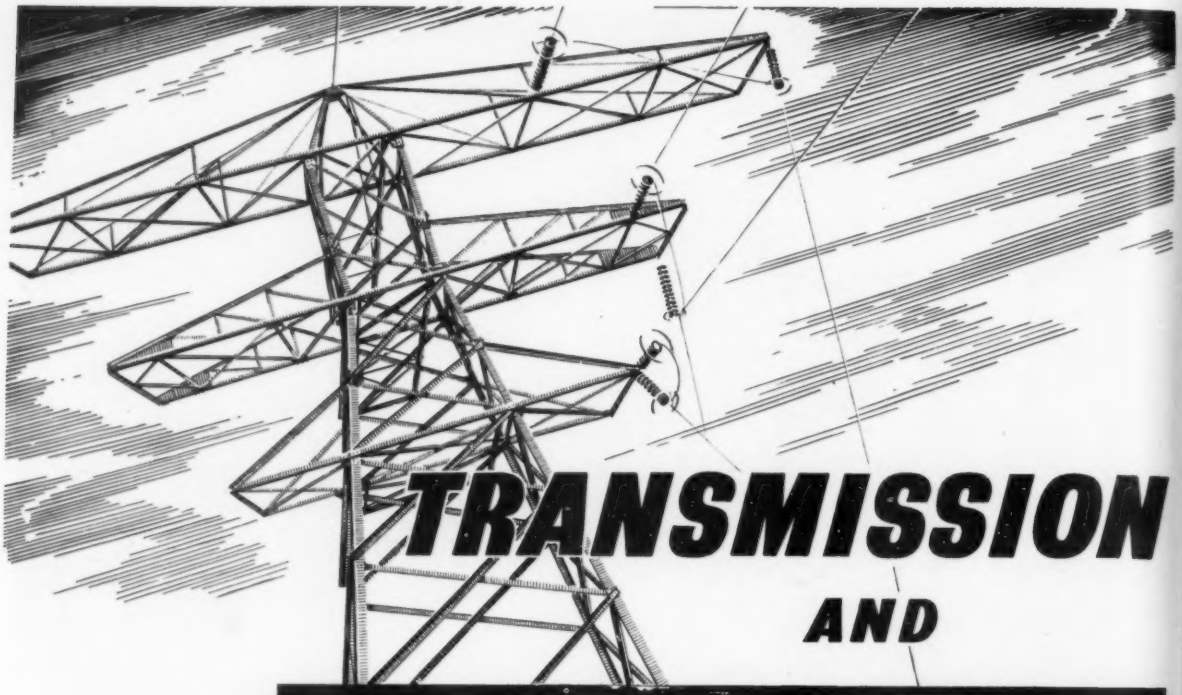

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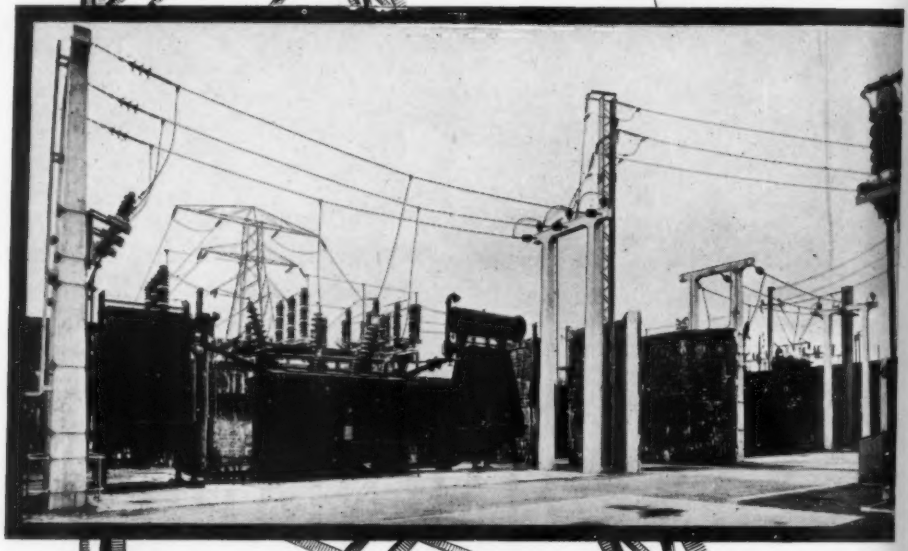

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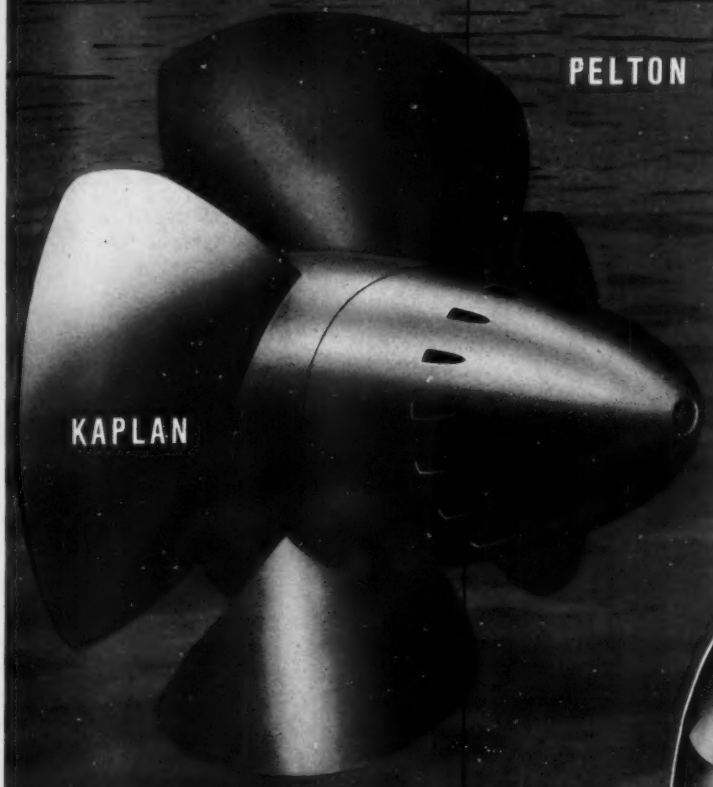

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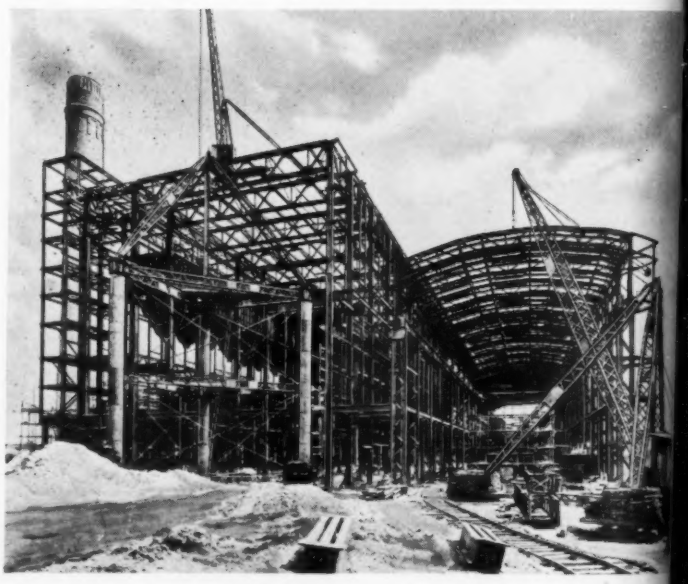

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The illustration is of Croydon "B" Generating Station in course of construction. Consulting Engineers: F. N. Rendell-Baker, M.I.E.E., C. S. Allott & Son.

SIR WILLIAM ARROL & COMPANY LIMITED, GLASGOW

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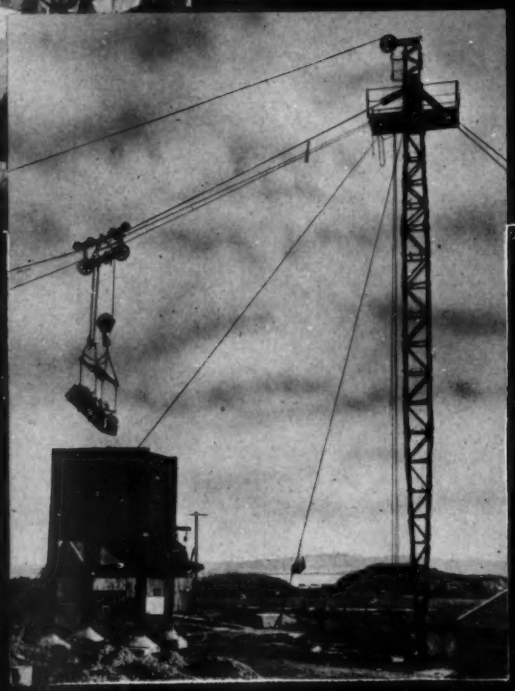

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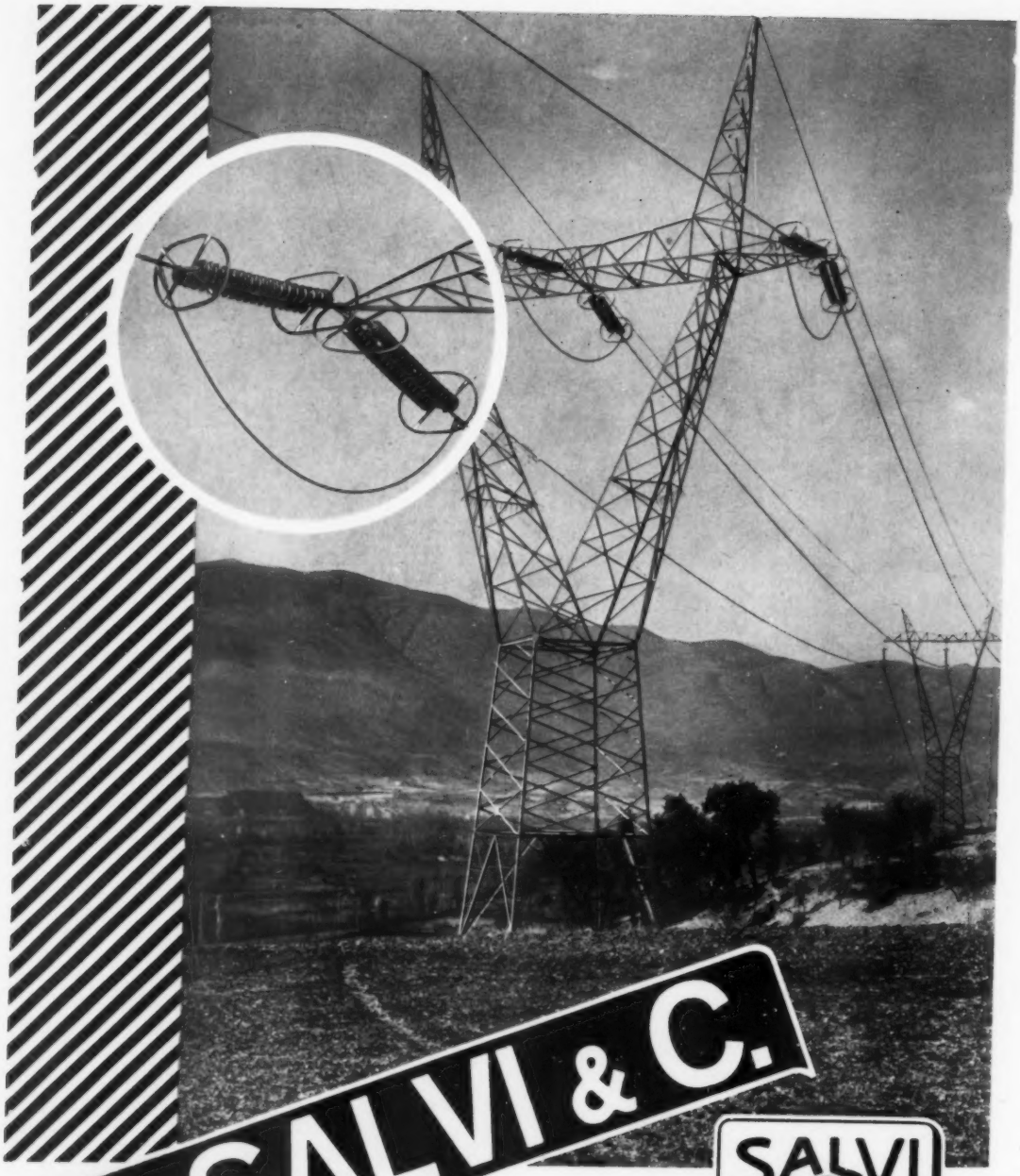

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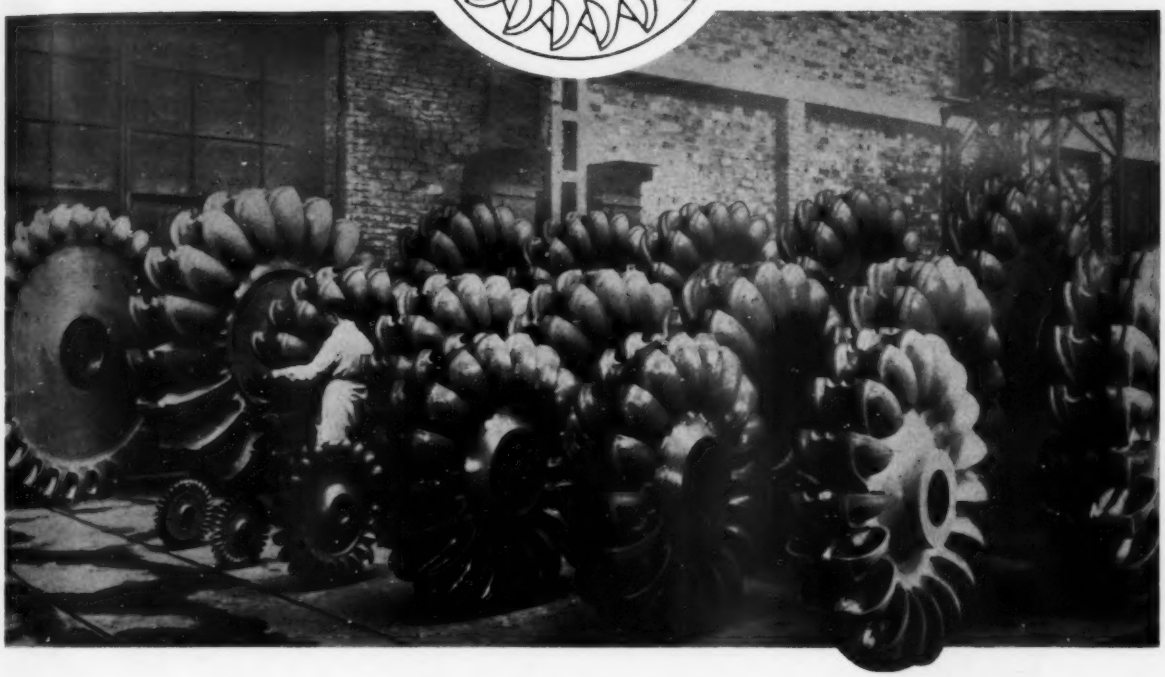

The total output of Pelton Turbines built by RIVA amounts to nearly 4,000,000 H.P. and includes Impulse Units for heads up to 3,940 feet and outputs up to 80,000 H.P.

RIVA are building two Pelton Turbines, each of 62,000 H.P., which are believed to be the largest single runner units operated by a single jet that have yet been manufactured. Head 1030m, Speed 500 R.P.M.

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The runner of each Turbine is machined from a single piece stainless steel casting with the buckets forming an integral part of the casting. The diameter of each runner is 3,180 m/m and weighs about 16 tons.

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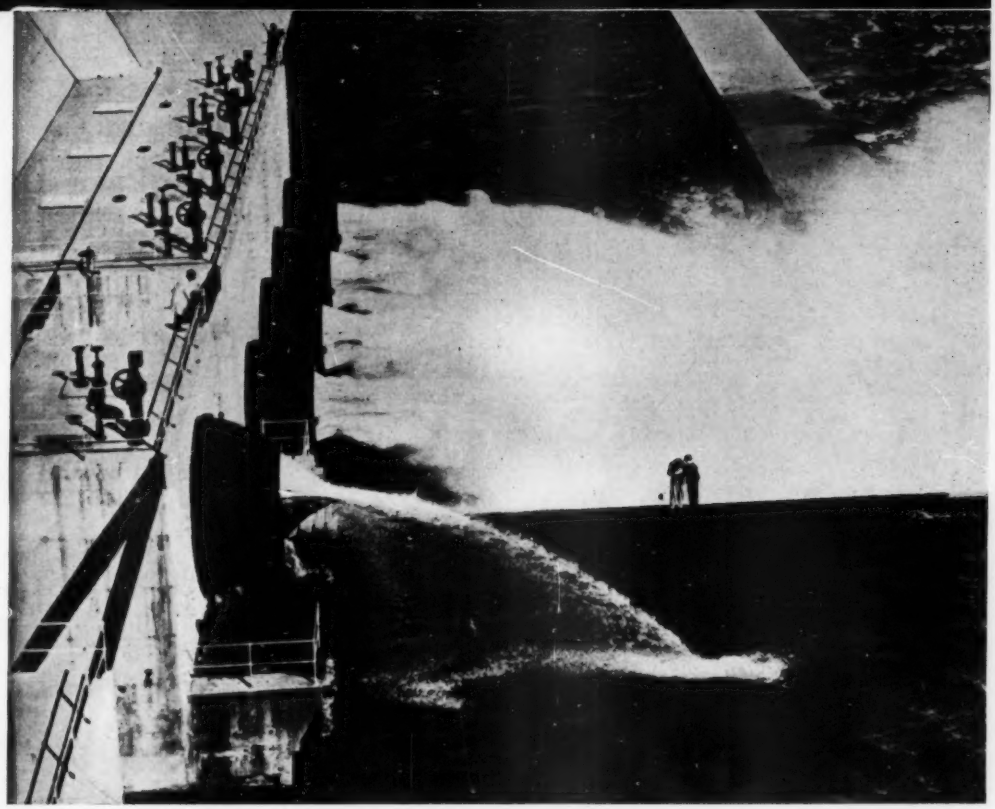

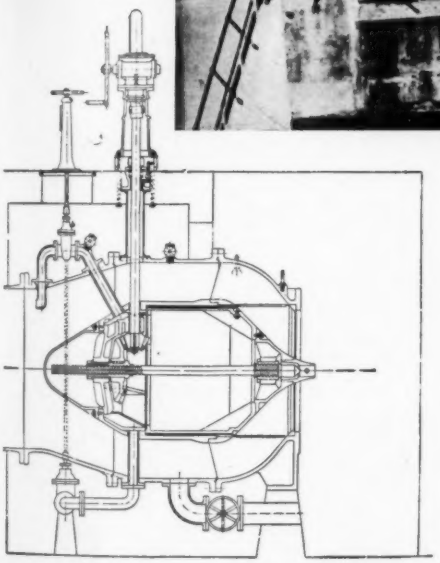

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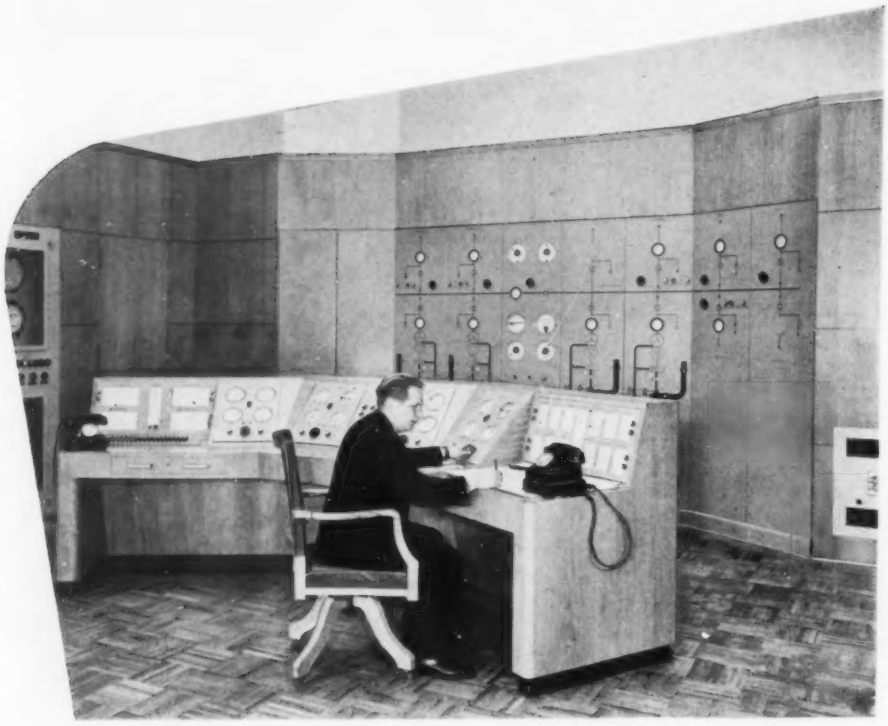

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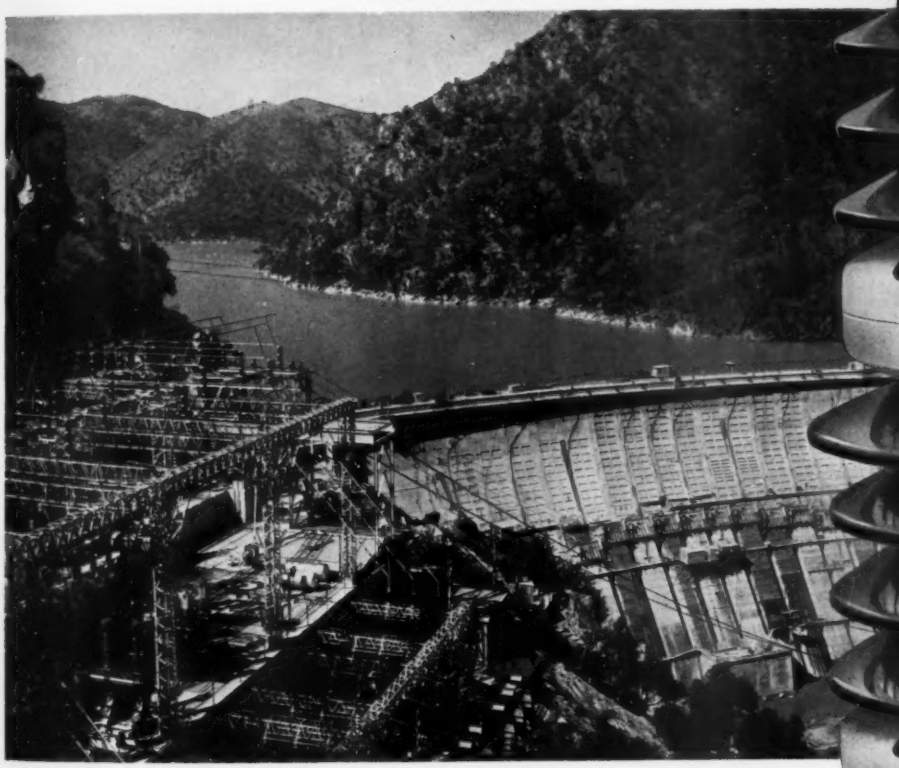

The Burrinjuck 132 kV Switching Station was equipped with Cylindrical Post Insulators type P.703. This is one of many stations on the New South Wales Public Works Department system equipped throughout with S.P.P. Post Insulators for 110kV and 66kV.

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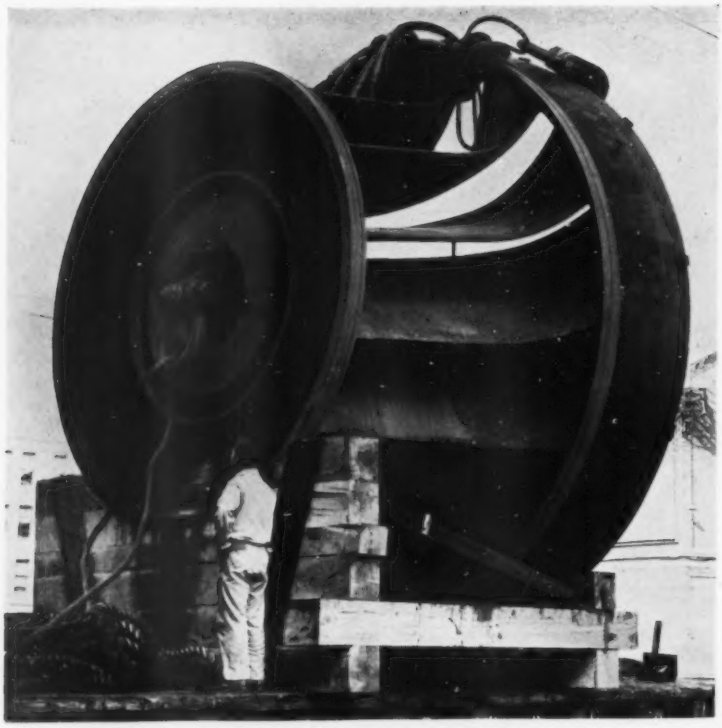

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OVER EIGHT MILLION HORSEPOWER

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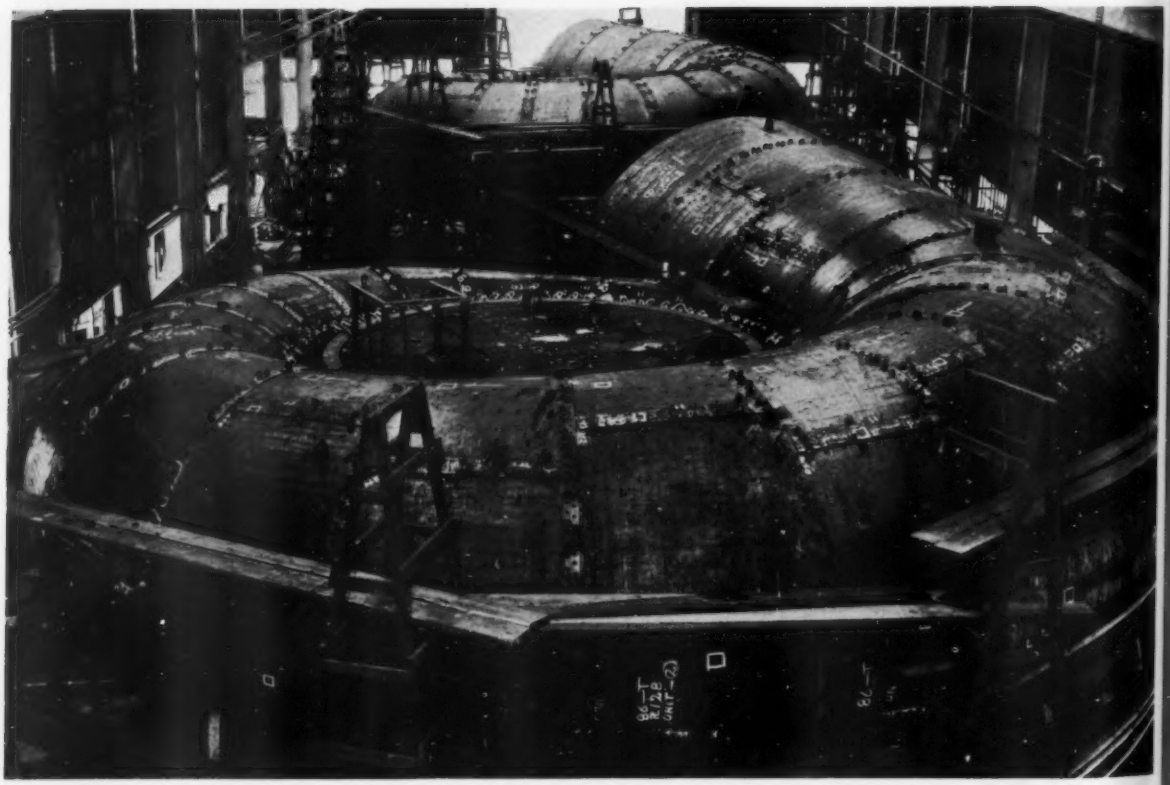

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HYDRO-ELECTRIC SCHEME

Portugal

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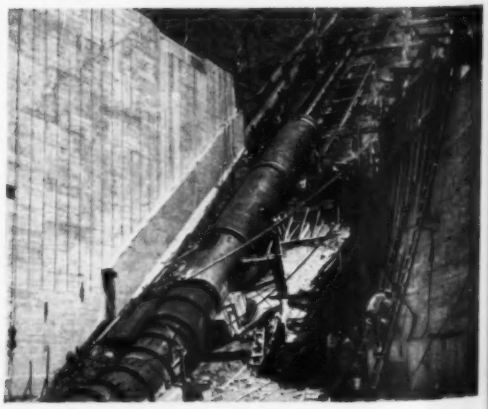

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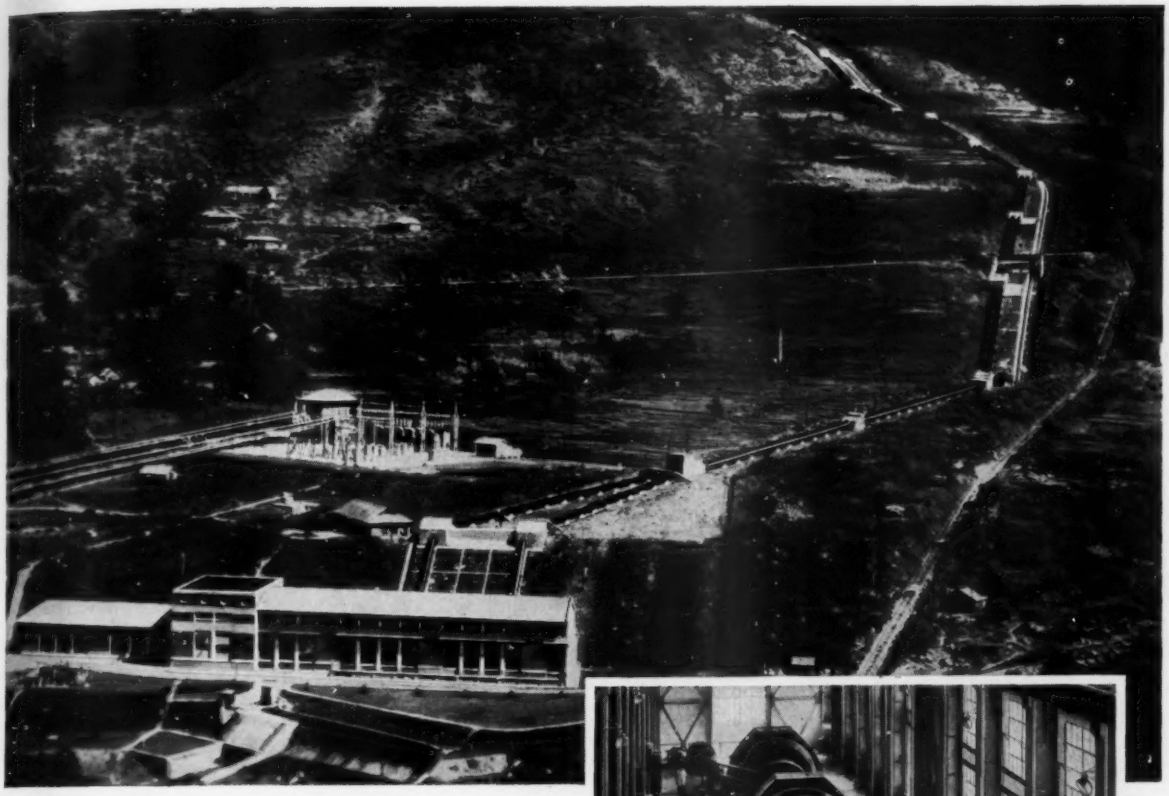

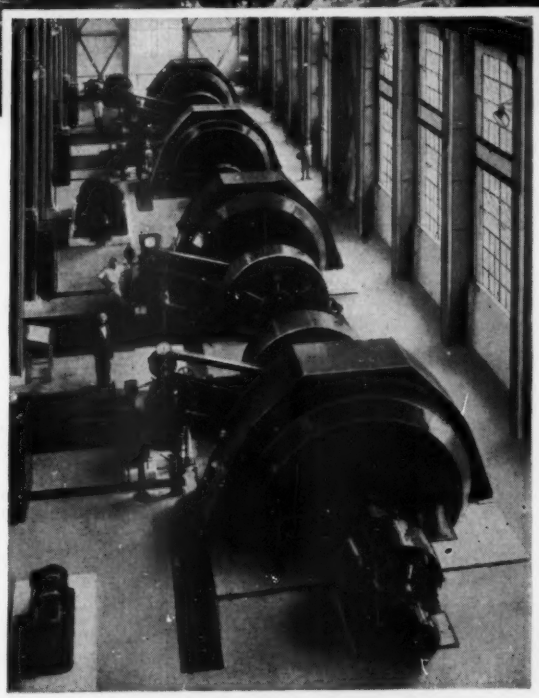

General view of Shanan Power Station

Four three-phase, waterwheel-driven alternators, (horizontal type, 13,333 kVA., 428 r.p.m., 11,000 volt, 50 cycle) installed in Shanan Power Station for the Punjab Government's Uhl River Hydro-electric Scheme.

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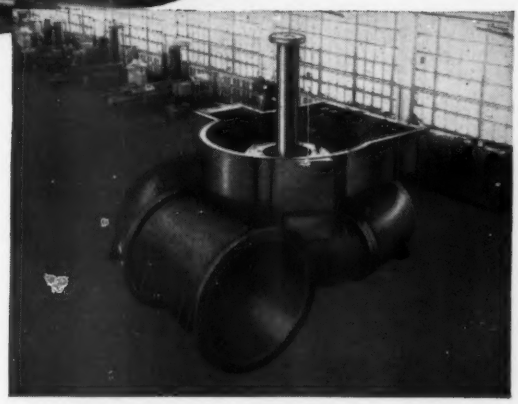
The *"Anderson Ranch"* POWER PROJECT
United States Bureau of Reclamation



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With a structural height of 456 feet, a base width of 2,650 feet and a crest length of 1,350 feet the Anderson Ranch Dam contains nearly 10,000,000 cubic yards of earth and rock. The reservoir behind the dam will hold 493,200 acre-feet of water.

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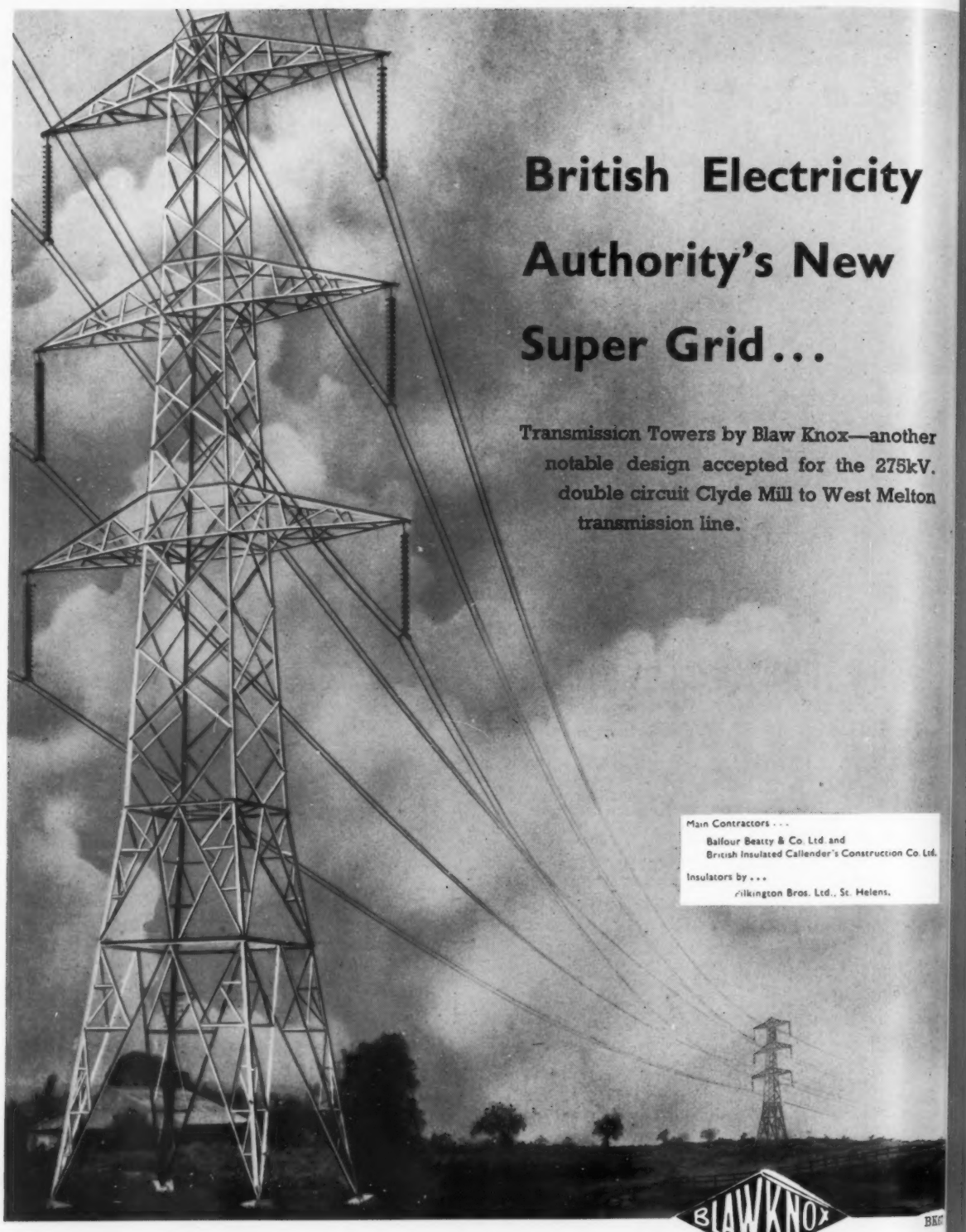
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CONTENTS FOR FEBRUARY, 1952

Leading Article: More Knowledge Needed - - 41

Editorial Notes - - - - - 42

The Tiber Valley Scheme - - - - 44

An American Municipal Power Scheme - - - 48

An Indian Tour - - - - - - 54
By John Warnock

Water Power in Africa - - - - - 57
By G. H. Lepper, A.M.I.E.E.

Hydro-Electric Resources of Belgium and the Belgian Congo - - - - - - 59
By L. de Heem

New Power Developments at Niagara Falls - - 62
By J. J. Traill

Design of Unlined Spiral Casings—1 - - - 65
By Dr. Charles Jaeger

Aggregate Production at Owen Falls - - - 71

The Influence of the Boundary Layer on Flow Characteristics - - - - - 74
By Professor L. Escande

Short Articles - - - - - - 76

Abstracts from the World Technical Press - - 77

Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
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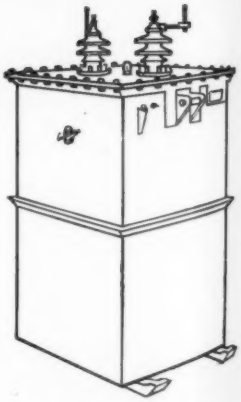

Further information on the use of capacitor banks is contained in Publication No. 278V *available on request.*

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WATER POWER

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More knowledge needed

IN these days the hydro-electric art is reasonably well documented. The pages of WATER POWER alone contain a formidable amount of information about very many aspects of the harnessing of nature's resources for the benefit of mankind. Roughly, the various branches may be divided into civil-engineering work, hydraulic design, mechanical engineering, and the work of the electrical engineer in generating, controlling and transporting the energy produced. In all these fields the broad principles are set out, each in scores of textbooks. New breaches in the frontiers of knowledge are continually being made.

There appears to be one aspect of hydro-electric practice, however, on which there is less published information than in any other branch. It relates to the behaviour of large civil-engineering structures after lengthy periods of time, and to the remedial measures which it has been found necessary to apply when difficulties have occurred in such structures.

Although rivers have been dammed for centuries past, it is only within the last hundred years that large numbers of extensive dam structures have been built. It is fair to say that only within the last fifty years have fully scientific methods been used in the surveying of the underlying rock, the planning of the types of material to be used, and the scientific control, for example, of the temperature of the cement on cooling. Nowadays all these matters have been the subject of attention at the highest levels of theoretical and experimental study, leaving little to empirical design and local judgment. In spite of this, some structures have given rise to troubles through seepages and cracking of concrete, while in other reservoirs the surface of the water-resisting side of the dam, which apparently chips and scales after every winter encrustation of ice, needs continual maintenance.

The deflection of the whole structure under lengthy periods of full water pressure and its relation to the natural elastic limits of the materials used, is a subject on which there is no great wealth of information. The experiences of civil engineers in regard to maintenance and remedial measures have been seldom made the subject of papers before Institutions, or of articles in the technical press. Perhaps this is because no one likes to discuss troubles which in some cases may be directly traceable to faults in the original design.

Some dams have sighting marks and specially designed optical apparatus, whereby a number of these marks are related to fixed points outside the dam area, so that regular records can be taken of any movement on any part of the structure. There appears to be no standard method of assessing these readings, and comparison between results obtained at one dam and those found at another is difficult. It is possible that some body, such as the International Commission on Large Dams (a part of the World Power Conference) might endeavour to co-ordinate structural deflection measurements. If this were done in such a way that engineers in one part of the world could usefully and accurately compare their figures with those obtained at generally similar sites perhaps on another continent, much progresss might be made towards the elimination of small but costly defects, and incipient major troubles might be averted long before they have grown to serious proportions.

The deflection question, touched on above, is only one aspect of civil-engineering maintenance: the pH value of the water has a bearing on the type of lining used on the upstream side of a dam, and its life under service conditions. The use of pressure grouting for stopping leaks through the decayed rock edges of a reservoir is another operation sometimes needed in the case of seepage after some years of service. Leaks through contraction joints in arch dams have been known to occur; and many special methods, some of the nature of a rapid improvisation, have had to be employed to remedy the trouble.

All these aspects of civil-engineering maintenance, and many more, are subjects upon which more theoretical and practical information is needed. Engineers have always been ready to pass on their experience to those who may benefit when faced with similar difficulties, and here surely is an opportunity in point.

St. Lawrence Seaway and Power Project

A SUBJECT commanding great interest in both political and engineering circles in America at present is the St. Lawrence Seaway and Power Project. The construction of power plant and of a deep channel through the St. Lawrence river from the Great Lakes to the Atlantic Ocean has been before Congress and the American nation since 1897. So far Congress has taken no action but Prime Minister St. Laurent of Canada has informed President Truman that his country may decide to build the seaway alone. An agreement was announced last December between the Canadian Government and the Provincial Government of Ottawa to develop hydro-electric power in the Internal Rapids of the St. Lawrence river as part of the seaway scheme. The President is said to have endorsed the plan as "the second best," pointing out, however, that he is still in favour of joint construction of the project. In Washington, pronounced apathy towards the St. Lawrence project is reported, in contrast to the vigorous support it aroused under the Roosevelt administration. There seems little American objection to a wholly Canadian approach to the construction of the seaway, although such unilateral action might be considered to constitute a violation of the Canadian-American boundary waters treaty of 1909. As yet there is not even an approximate indication of how much the seaway and the hydro-electric plant together will cost. A recent figure of 1,500 million dollars is said to be little more than a guess.

Grand Coulee Power Plant

THE largest hydro-electric power plant in the world was completed when the eighteenth and last generator went on the line at Grand Coulee dam, in Central Washington, on September 14, giving the plant a 1,974 MW generating capacity. The new generating unit will produce 108 MW. But large as the plant is, there is already discussion of the possibility of further expansion by adding a third group of generators to help to meet the rising power demands of the Pacific North-West of the United States. Because of the large power demand, the generators are frequently and safely run at capacities 20 per cent. greater than their rated 108 MW per unit. It is claimed that the world's record for hourly production of hydro-electric energy at one plant was recently set in excess of 2,000,000 kWh for the first time in history.

Hydrogen-Cooled Alternators

BY the application of hydrogen cooling to alternators some 16 years ago the ratings of alternators were increased about 20 per cent. for a given frame size and since then the gain has been gradually increased to about 35 per cent. by steady improvements in design. The Allis-Chalmers Manufacturing Company of America has now applied a new technique to hydrogen-cooled alternator design by which it is claimed that the output has been raised by 70 per cent. for an equivalent amount of material. This is the result of approaching the design from basic principles instead of seeking to adapt machines initially intended for air cooling. The new system is known as supercharged cooling, because a modified centrifugal compressor is used, with high velocities in the rotor cooling ducts. The multi-stage compressor is of larger diameter than the rotor, but being mounted at one end of the rotor shaft, does not interfere with or complicate rotor removal. A considerable reduction in active rotor length is achieved, and though a slightly larger exciter is required, the overall length of the alternator set is appreciably shorter, so that savings can follow in building costs. Certain technical improvements in performance are also secured. The first supercharged hydrogen-cooled turbo-alternator was placed in service at the Wisconsin Power and Light Company's Edgewater plant in Sheboygan, Wisconsin, in June, 1951, and was rated at 60,000 kW, 12,500 V, 3,600 r.p.m.

Owen Falls Scheme

FOUR turbo-alternator sets are to be put into service progressively at the Owen Falls hydro-electric scheme in East Africa during 1953 and 1954. Two further units will be added in 1955 and the remaining units will be installed as the demand for power grows. The Owen Falls scheme, on the White Nile two miles downstream from Lake Victoria, was started in mid-1950 and is being built by the Uganda Electricity Board. It consists of a gravity dam 2,725 ft. long, the maximum height of which is 85 ft. Six control sluices, each 6 ft. 9 in. wide, which are to be constructed at the centre of the dam will be capable of taking a maximum recorded flow of 43,000 cusecs. In addition to the main dam there are two short dams forming the sides of the headrace channel to the power house and the intake dam immediately upstream of the power house containing the control gate and screens for the turbines.

Second Hydraulics Conference

THE "Société Hydrotechnique de France" announces in Vol. II of its proceedings that its second conference on hydraulics ("Deuxièmes Journées de l'Hydraulique") is to be held on June 25, 26 and 27, 1952, in Grenoble. The main object to be discussed at this conference, Transport and Decantation of Solid Matter, will be dealt with in three sections: Application of general theories to the transport of solid matter, transport of solid matter in conduits, and decantation and filtration of solid matter in closed and open systems. The Conference is to be followed on June 28 and 29 by visits to engineering works, laboratories, experimental stations, and hydro-electric plants. Further information can be obtained from the "Société Hydrotechnique de France," 199, rue de Grenelle, Paris VII.

Ontario Hydro Board Report

THE report for 1950 of the Hydro-Electric Power Commission of Ontario records that four generating stations — George W. Rayner, Pine Portage, Des Joachims and Chenaux — commenced operation during the year, substantial progress was made on Otto Holden (la Cave) station, and preliminary work was carried out on Sir Adam Beck No. 2. The Commission's two largest steam stations — Richard L. Hearn at Toronto and J. Clark Keith at Windsor — were also well advanced. Despite the heavy increase in the cost of living due to the war, the cost per unit to urban domestic consumers had fallen from 1·28

cents in 1938 to 1·04 cents in 1950, to urban commercial consumers from 1·62 to 1·41 cents, and to farmers from 2·11 cents in 1944 to 1·847 cents in 1950. Between 1945 and 1950 the average consumption per domestic consumer rose from 205 to 304 kWh, and per commercial consumer from 627 to 832 kWh. The number of rural customers rose from 156,560 to 292,811 and the peak rural load from 132,572 to 314,681 h.p.

Special reference is made in the report to the Niagara Diversion Treaty concluded with the United States in 1950, in accordance with which it was possible to put work in train on Sir Adam Beck No. 2 station, and the need is emphasised to harness the St. Lawrence river if power supplies are to be ensured beyond 1956.

More Swedish Electric Power

SWEDEN received an important addition to her electric power supplies recently when the second power plant began operating at the new Harspranget power station which we described last month. The first plant, which started operating in March last, is producing some 15,000 kW more than estimated, its total capacity now being 115,000 kW. The capacity of the second plant is estimated to be of the same order. The Harspranget station will be completed in April when the third and last of the units starts operation.

Power Supply Threat

EXCEPTIONAL autumn drought has caused serious problems for Sweden's power supply. The inflow to the most important power-producing rivers was less than half the normal, and the reservoirs were filled only to 70 per cent. of capacity, while the consumption of power exceeds that of last year by five to ten per cent. Production has had to be stepped up at the steam-power stations during the past month or two.

Formosa to get Westinghouse Power Equipment

THE Taiwan Power Company, of Taiwan (Formosa), has placed a series of orders with Westinghouse Electric International Company for apparatus which will provide protection and communication on the primary transmission lines serving major industrial centres of the island, it was announced recently. Being purchased under the E.C.A. Far Eastern programme, the equipment includes telemetering, protective relay and power-line carrier communication apparatus. Telemetering equipment will supply information to the load-dispatching office at Taipeh, the capital, from the island's main source of power in the Sun-Moon Lake region of central Formosa. Relaying equipment will be installed on the 140 kV transmission lines to provide protection against phase and ground faults in one-sixtieth to one-twentieth of a second. The three terminal lines in the Sun-Moon Lake region will be provided with carrier relays, while the remainder of the lines will have conventional high-speed distance relays. Communications equipment was recently shipped for installation on the lines which extend the length of the island from Patu in the north to Kaohsiung, chief industrial city and location of aluminium, fertiliser, cement, machine-tool and other industries. The apparatus is intended to ensure continuous operation of the power system, which is expected to add about 100,000 kW of installed capacity in the next few years to serve a waiting list of industrial power consumers.

Hydro-Electric Business Benefits Manufacturers

THE tremendous impetus given to the production of hydro-electric plant and equipment in Scotland by the programme of development in the Northern Highlands is indicated in current New Year reports from several of the larger manufacturers. Previous to the launching of these schemes the actual output of hydro-electric equipment by Scottish firms was unimportant; since their inauguration the scope and output has expanded continuously, as has the experience in practice. There are now many firms working on hydro-electric equipment in Scotland, serving not only the North of Scotland scheme but also hydro-electric developments abroad. It is a fair prospect that this work will be expanded steadily and a new engineering industry for Scotland may be said to have grown up in the last few years. Edinburgh has become an important centre for hydro-electric plant, and it is now possible to secure a complete installation of the largest type suitable for use anywhere in the world, completely, within ten miles of the city. Bruce Peebles and Co. Ltd. have done outstanding work in this connection as main contractors. They have booked an order for a 2,400 kW induction generator set, believed to be the largest in Britain, for installation at the foot of the 86 ft. shaft at the Loch Mullardoch end of the 3¼ mile tunnel feeding Loch Benevean on the Fasnakyle scheme. The position has now been reached where the main problem involved is that of transportation, so large and heavy have the hydro electrical and electrical units become. Large motors of around 8,000 b.h.p. for many applications have been sent abroad with Australia, Canada, South Africa, Tasmania and Portugal among the buyers. Transformer demand remains intense at home and abroad. Large capacity transformers on order are a record for this important company. Canada, India, South Africa, New Zealand and the Middle East are among the destinations.

Another aspect of hydro-electric operation has been the expansion of the tool industry. Consolidated Pneumatic Tool Co. Ltd., of Fraserburgh, have entered 1952 with a record order book, in which drills and compressors for tunnelling and similar work take a prominent place. These orders have been stimulated immensely by hydro-electric activity — again emphasising the increasing value of the schemes as a stimulation factor in engineering as distinct from their obvious importance as a source of power.

Tothill Press Limited

Tothill Press Limited, the company owning and publishing this journal, has taken a 99-years' building lease on the triangular site of St. Margaret's School, Dean Farrar Street, Westminster, at the rear of its present offices. The site, which covers nearly half an acre, is owned by the London Diocesan Board of Education, and in due course offices consisting of basement, ground and five upper floors are to be erected and used for the purpose of developing the company's business.

Fig. 1. Panoramic view of the downstream side of the Castel Giubileo dam and power station

The Tiber Valley Scheme

Castel Giubileo, the first of a series of stations projected to develop the river Tiber, is now in operation.

WITH the opening of the Castel Giubileo station about seven miles north of Rome, the first stage has been completed of a £60 million scheme which is estimated to produce 1,000 million kWh per annum and possess a reserve of a further 1,000 million kWh. The scheme began to take shape in 1941, when the Terni Company and the Società Imprese Centro Italia set up the Consorgio Forze Idriche Tevere to develop the project.

The complete scheme will cover the rivers Tiber, Chiani, Paglia, Marta and Arrone and their associated lakes Bolsena, Vico and Bracciano, and an outline map is given in Fig. 2. The scheme will be divided into five main sections: (1) The river Chiani will be dammed in the Poggio Ancaiano district to form a 160 million cu. m. reservoir serving a station on the Tiber at Corbara. (2) The Tiber will be dammed at the Corbara Narrows to form a 180 million cu. m. reservoir serving an underground station at Baschi. Other stations are also projected on the Tiber at Orte, Foglia and Nazzano, and that at Castel Giubileo has now been built. (3) Lake Vico will be made into a permanent reserve of 600 million cu. m. and pumped-storage and generating plants will be built at Civita Castellana and Casale, the latter being underground.

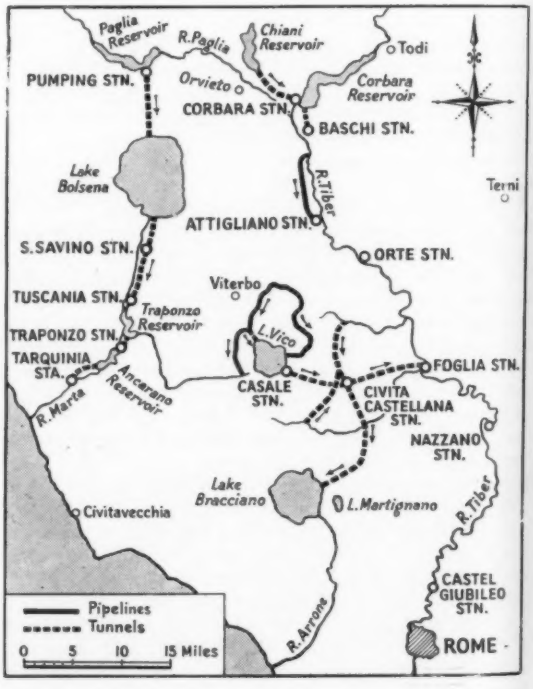
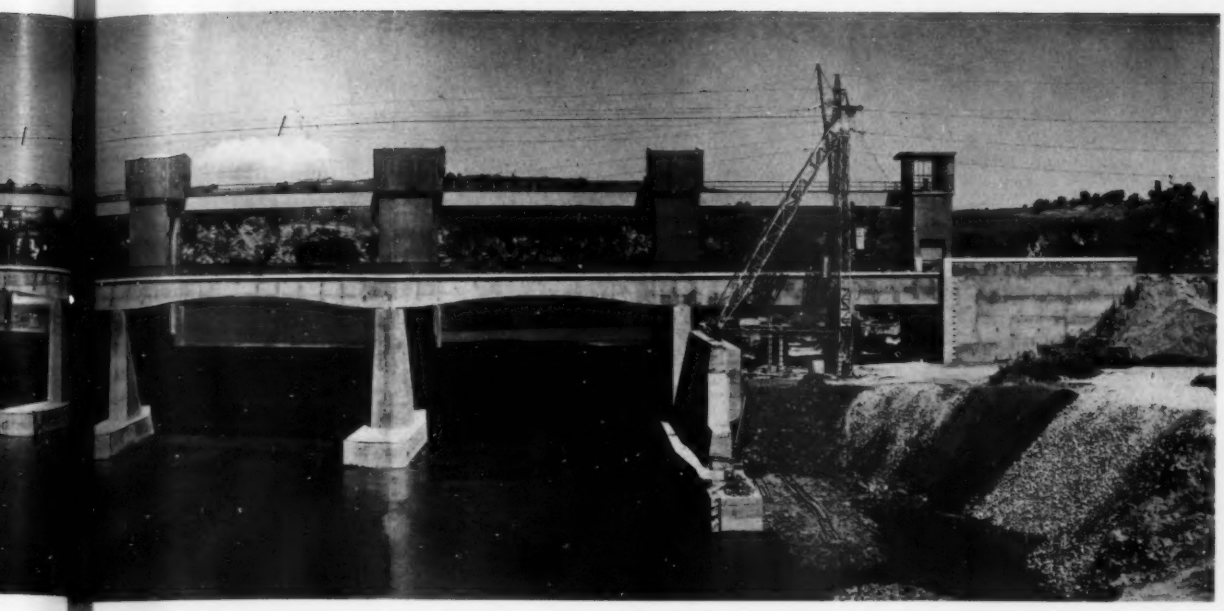


Fig. 2. Sketch map of the Tiber Valley scheme



(4) Lake Bracciano will be linked with lake Vico and converted into a permanent reserve of 275 million cu. m., and will supply a generating station on the Arrone. (5) The river Paglia will be dammed to make a 30 million cu. m. reservoir from which water will be pumped to lake Bolsena, which will constitute a permanent reserve of 170 million cu. m. Four stations are to be built at S. Savino, Tuscania, Traponzo and Tarquinia to use the waters from lake Bolsena.

Castel Giubileo Station

At Castel Giubileo the river has a mean free water level of 10·9 m. above sea level, a maximum flood discharge of 2,500 cu. m. per sec. and a minimum dry-weather flow of 80 cu. m. per sec. A dam has been thrown across the river to raise its level to 17 m., giving a mean head of 6·10 m., a maximum head of 8·50 m., and a minimum of 3·50 m.

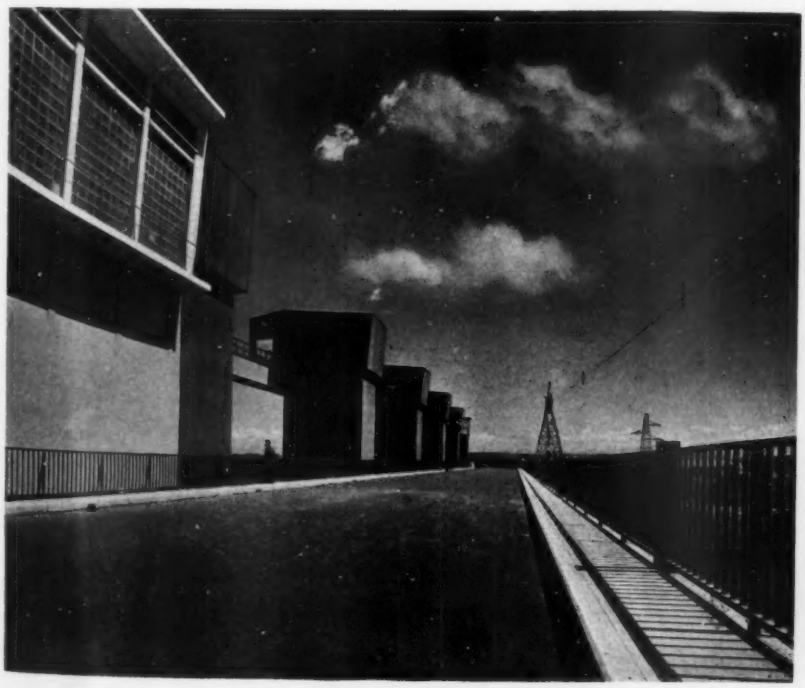


Fig. 3. A view along the road bridge spanning the dam

As will be seen from our titleblock, the power-house structure forms the right-bank end of the dam, and the spillway section has four openings. To construct the spillway, compressed-air cofferdams were sunk to build three piers, 29·75 m. by 7 m., and two abutments, 29 m. by 6 m. and 33 m. by 6 m. respectively. Further cofferdams were sunk to build the four bays of the spillway, which are completely faced with granite blocks and lead to a stilling pool 11 m. long consisting of a reinforced-concrete monolith having a minimum thickness of 2·5 m.

Cofferdams were also employed to construct the draught-tube chambers and the foundations for the power house, the

generator room of which measures 52·5 m. by 15·5 m.

Clay was encountered on the left bank, the bed of the river and the right bank being sand.

Each spillway section is 20 m. wide and is equipped with a Terni sliding-type sluice gate 9·3 m. high. Each gate is divided into two sections so that light floods and floating objects can be released without raising the whole gate. The upper section is 1·8 m. high and the lower section 7·5 m., the total weight of each sluice being 160,000 kg. The gate-operating mechanism was supplied by Societa Calzoni and consists of two oil-operated radial-vane-type motors for each section, the movement of the two motors being kept in step by a light link mechanism. Each section is sealed by two oil-operated jacks working on a separate oil circuit from the lifting gear.

Fig. 5. Placing the rotor of one of the 6,400 kV A alternators in position

Societa Calzoni also supplied the stop logs for isolating the sluice gates. Each stop log is in ten sections and has a total height of 8·5 m. and a weight of 60,000 kg.

An overhead gangway affords access to the various control towers and carries the oil piping and other services.

Fig. 4. Looking along the upstream side of the dam piers

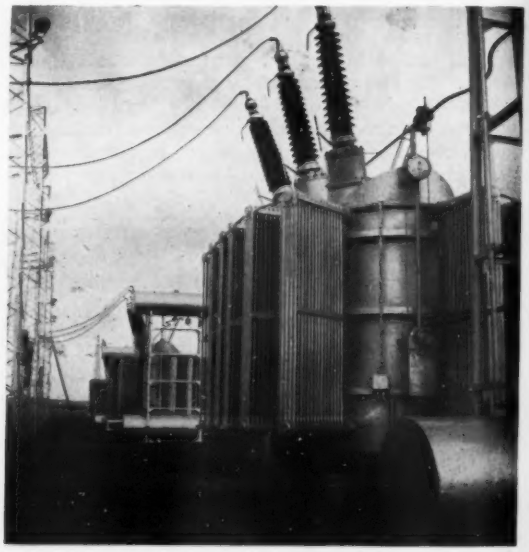


Fig. 6. Breda 6,400 kV A 10/120/150 kV transformers

In the power-house section of the dam each turbine draws its water through three intake openings, each 4·83 m. wide. Stop logs, 10 m. high, can be placed over each opening by a travelling portal crane and consist of four sections, of which the heaviest is 2·5 metric tons.

A De Pretto/Escher Wyss semi-automatic electrically driven trash rake is provided.

A road bridge, 620 yards long and 37 ft. wide is incorporated in the dam and replaces a bridge destroyed in the war.

Generating Equipment

The main generating equipment consists of three De Pretto/Escher Wyss vertical Kaplan turbines driving

Fig. 7. The control room at Castel Guibileo

Ansaldo/San Giorgio Oerlikon type alternators. Each turbine is rated at 7,850 h.p. at 107·2 r.p.m., the leading performance figures being given in Table I. The rotor has a flywheel effect of 1,000,000 kg.m² and weighs 50,000 kg., the thrust bearing being designed for a total load of 187,000 kg.

TABLE I

Net head ..... m.	4	6·50	8·20
Discharge ..... l./sec.	66,800	82,800	83,550
Horsepower ..... h.p.	2,850	6,120	8,030
Full-load efficiency %	80	85·3	88

Each alternator is rated at 6,400 kVA at 0·6 power factor, and generates three-phase 50 cycle current at 10,000 V. Cooling is on open circuit and is natural. A 249 kW main exciter and a 1 kW pilot exciter are mounted coaxially above each generator.

The current is handled in an outdoor substation, Fig. 8. Switching is carried out at 10,000 V by three Galileo 150 kV 400 A oil circuit breakers having a rupturing capacity of 6,000 A. These circuit breakers are succeeded by three Breda 6,400 kVA transformers supplying high-tension current at 120,000 and at 150,000

(Continued on page 53)

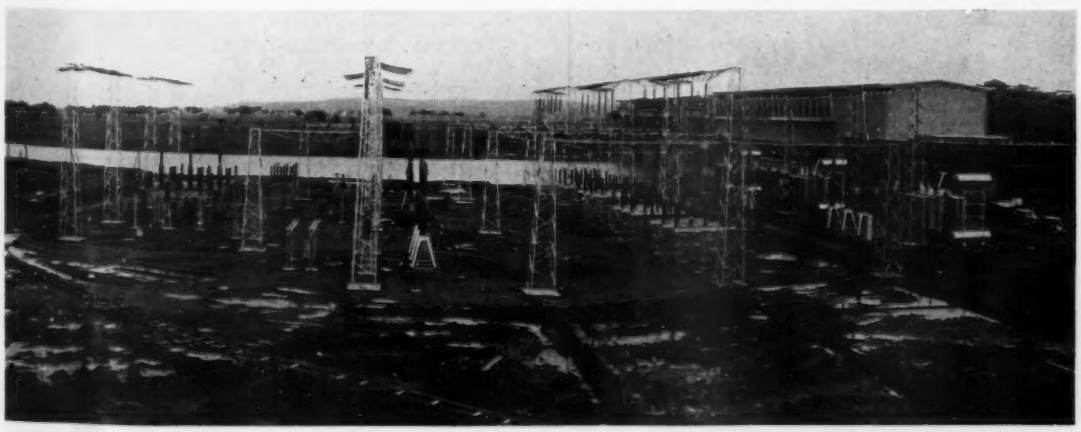


Fig. 8. The outdoor switching station alongside the Tiber

Fig. 1. View of Diablo plant showing the lake, dam and 132,000 kW power house

An American Municipal Power Scheme

Seattle City Light, which is one of the oldest municipally owned electric power systems in the United States, has undertaken a large programme of expansion.

FROM its first inception in 1903 Seattle City Light has been engaged in a constant struggle to meet an ever-expanding demand for power. It began its operations by throwing a timber crib dam across the Cedar river at Cedar falls, 27 miles south-east of Seattle, the first generating plant consisting of two 1,200 kW units which were put to work in 1904. By 1907 two further 4,000 kW machines were added, to be followed up in 1921 and 1929 by two additional 15,000 kW sets. By 1921 the demand for current had outstripped the possibilities of immediate hydro expansion and three thermo-cycle sets totalling 40,000 kW were put to work in a station at Lake Union, and this plant, to which no subsequent additions have been made, is still in operation today, though its role is chiefly that of providing a peak-load and standby service.

The general trend of development towards the end of the 1914-18 war suggested the necessity to search for further hydro-power sites and this led the late

Fig. 2. Site of the Ross power house being excavated. The penstock tunnel portals for the four 100,000 kVA generating sets will be noted in the foreground

Mr. J. D. Ross to the Skagit river at a point where it flows in a relatively narrow gorge and where the bed has a drop of no less than 700 ft. in a distance of 15 miles. This stretch of the Skagit afforded excellent sites for three storage dams and power stations, and although technical problems cropped up in abundance they were gradually overcome. In the first place there was no railroad and 23 miles of rough country had to be traversed by trail. The railroad was completed in 1919 and allowed the installation of a 2,000 kW plant at Newhalem, and although this was built for temporary service, to provide the power required for the Skagit projects, it is still contributing power to the major network.

The Skagit river is the largest tributary to Puget Sound and cuts through a deep gorge in the Cascade mountains about 100 miles north-east of Seattle and about 20 miles south of the Canadian border. Flow varies from a minimum of 470 cusecs to a maximum of 70,000 cusecs, the average being 3,970. The steep fall of the river has made it expedient to build three successive storage dams and power stations—the Ross, the Diablo and the Gorge. The Ross scheme is not yet at the producing stage but a regulating dam has been constructed and a new power station is in course of construction. The Gorge plant was started up in 1924 with a capacity of 40,000 kW generated in two sets, and a third 20,000 kW set was added in 1929.

In the next year, 1930, the 389 ft. high dam was completed at Diablo higher up the river from Gorge, but the general depression which swept over the industrial world at that time caused progress to be arrested. Thus it was not until 1936 and 1937 that the two huge 64,500 kW waterwheel generators were installed, being at that time the largest in the world.

By this time the Seattle municipal system was generating current to the tune of 417 million kWh per annum, but the market, both industrial and residential, still called for more power, and it was this consideration that led to the initiation of the Ross scheme, above the Diablo station. This development far exceeds in magnitude the other Skagit installations and has wonderful potentialities for the generation of power. Before discussing it, however, it perhaps is as well to mention that the Gorge dam, the most downstream of the series, furnishes no storage but is for diversion purposes pure and simple. The Diablo dam impounds a lake having a storage capacity of 90,000 acre-feet, just sufficient to provide for daily regulation of the stream flow. But above the Ross site, the canyon spreads out to form a large basin which offers excellent opportunities for storage. When completed the Ross dam will thus create a reservoir of sufficient size to hold the entire flow of the river for more than 500 days and thus provide streamflow regulation all the year round, apart from very exceptional years. Not only will this degree of control increase the operational efficiency of the Diablo and Gorge plants but it will also provide a valuable flood control for the rich agricultural lands of the lower Skagit valley in the Mount Vernon area.

Construction of the Ross dam was begun in 1937, and the first step bringing the barrier to a height of 305 ft. was completed in March 1940. The second step, to raise the height to 475 ft. was begun in 1943, and the third step was commenced soon afterwards in an endeavour to meet the war demand for power. With the third step, which brought the height to 540 ft., the dam creates a storage lake of 1·4 mil-

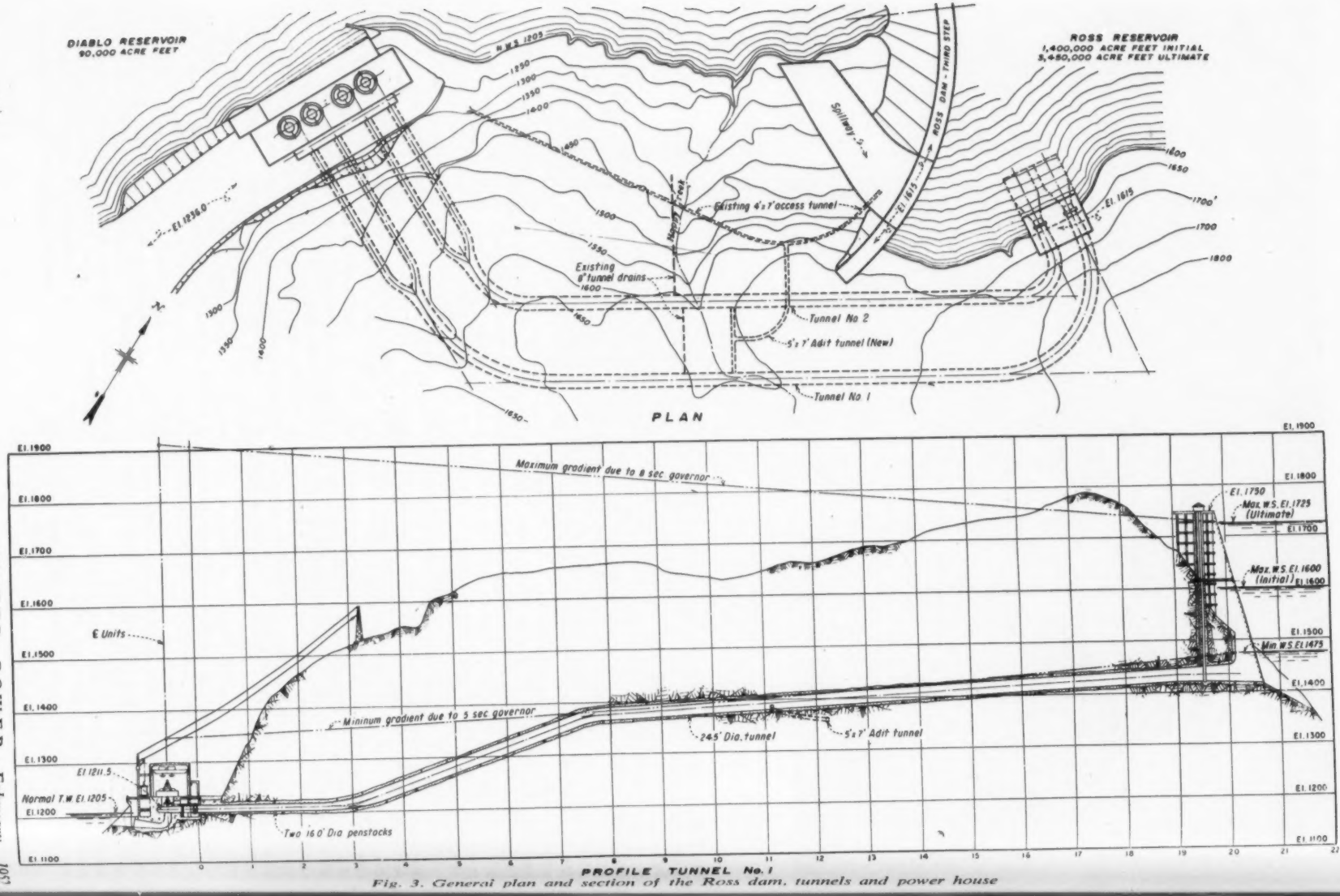


Fig. 3. General plan and section of the Ross dam, tunnels and power house

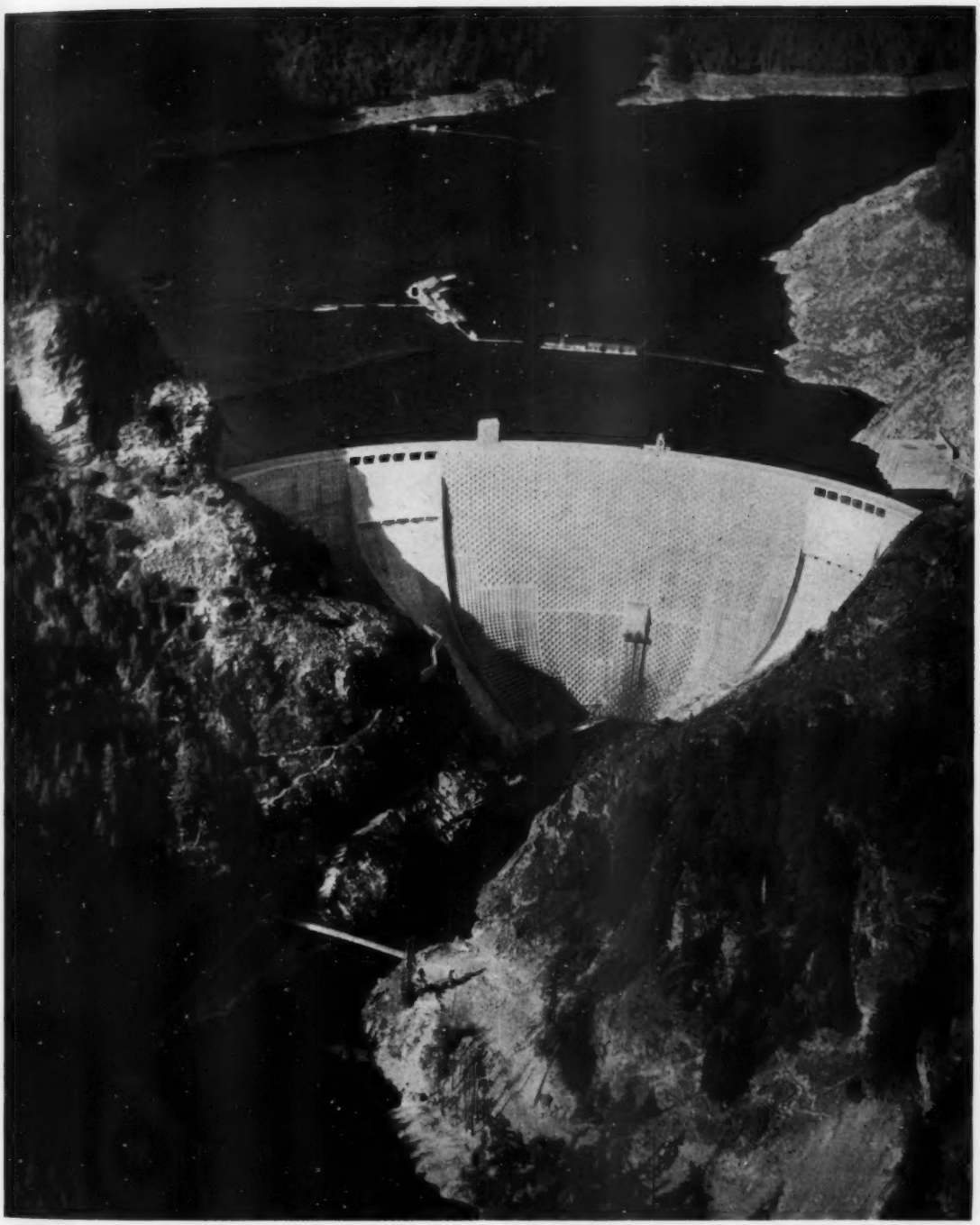


Fig. 3. General plan and section of the Ross dam, tunnels and power house

Fig. 4. An aerial view of the Ross dam, 540 ft. high and 1,300 ft. wide. The waffle construction on the face of the dam is to enable the height to be raised by another 125 ft.

lion acre ft. capacity and which extends to a length of 22 miles upstream and partly across the Canadian boundary. To indicate its value to the downstream installations it may be mentioned that it adds 580 million kWh per annum to the output of Gorge and Diablo. A new extension to the Gorge power house to accommodate a further generator was put into operation in July 1951, increasing the capacity of this station from 64,000 kW to 108,000 kW. In the meantime the original crib dam at the Gorge plant has been replaced by a masonry structure that will serve until a 375 ft. high dam is constructed, when the

Fig. 5. The extended Gorge power house showing the transformer bank for the new 66,700 kVA generator

Fig. 6. Close-up view of one of the spillways showing the waffle construction of the dam face

present operating head of 294 ft. will be increased to 385 ft., thereby increasing the capacity to 150,000 kW.

Initially, the turbine runners at Ross, which are rated at 120,000 h.p. each, will be designed for an effective head of 355 ft., but after the dam has been raised to its ultimate height of 665 ft., these runners will be exchanged for 140,000 h.p. runners designed for a head of 440 ft. They are being manufactured by the Baldwin-Lima-Hamilton Corporation. The 100,000 kVA generators (90,000 kW at 0·9 power factor) are wound for 13,800 V 3 phase 60 cycles and are being manufactured by the Westinghouse Electric Corporation There will be six single-phase transformers, each 70,000 kVA capacity, stepping up from 13,800 V to 230,000 V, the General Electric Company having secured this contract.

As will be seen from our illustration of the Ross dam in Figs. 4 and 6, the face has been cast in a waffle pattern to provide a firm bond between the old and new concrete when the structure is enlarged to its final height of 665 ft. One of the most troublesome incidentals to this storage dam was the clearing of the basin upstream for a distance of some 25 miles. The valley ranges between one and three miles in width and the flooded area contained 360 million feet, board measure, of merchantable timber. All this has had to be removed, and as much of it is on steep ground the task has been formidable. To complicate matters the logs could not be floated downstream because of the dams and as there was no vehicular road above Newhalem, contractors refused to bid. Finally, a way out was found by taking the timber over a roundabout route through Canada.

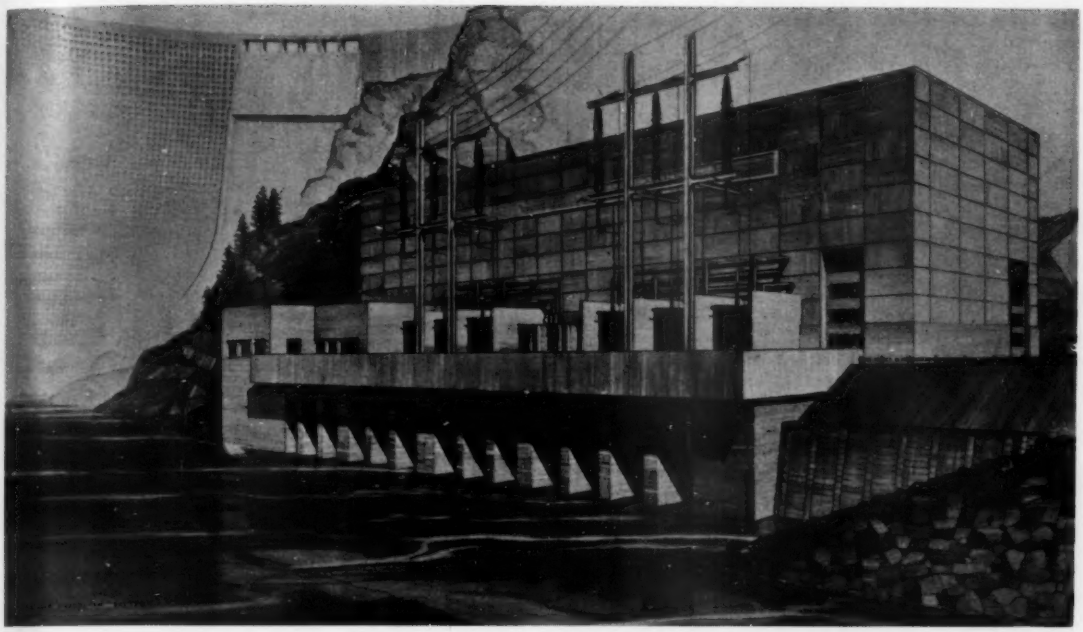


Fig. 7. An architect's sketch of the new Ross power house

At its present height the dam has a roadway elevation of 1,615 ft. above sea level, and a spillway elevation of 1,582 ft. The roadway portion is 1,300 ft. long and 33 ft. wide. At the base the dam is 208 ft. thick and contains, in all, 909,214 cu. yards of concrete.

Fig. 6 shows one of the hooded spillways; this structure has an extreme vertical drop and the hoods are designed to train the water down so that it will not leave the spillway after passing the rollers.

Work on the Ross power house is now in hand (Fig. 7), and is expected to be completed in 1953, by which time three 100,000 kVA turbo sets will have been installed. Ultimately there will be four generating units and although no strict time schedule has yet been decided for the installation of the final set it is hoped to have it working by 1956. Water will be delivered to the turbines through two 1,900 ft. long tunnels, concrete lined and 24 ft. 6 in. in diameter. The average effective head with the present elevation of the dam will be 355 ft., and it may be that the station will have to operate at this head for some time, as the heightening of the dam by a further 110 ft. will necessarily be an expensive undertaking and is estimated to take eight years to complete after the awarding of the contract. When reared to its final height, 665 ft., the dam will impound nearly 3½ million acre feet and the reservoir will be 30 miles long, extending over eight miles beyond the Canadian border. With the dam at this height and the fourth generator added, the Skagit scheme will have an aggregate capacity of 645,000 kW.

Energy from the new generator at Gorge and the whole of the Diablo set is transmitted to Seattle at 230,000 V. At present the current from the three older sets at Gorge is transmitted at 165,000 V but will be integrated into the 230,000 V transmission system this year.

A point of importance is that the Seattle City Light network is linked up with those of the Tacoma City Light, the Bonneville Power Administration and eight other private power systems, forming a vast electrical grid which spreads over five States and extends even into British Columbia. This network functions under the name of the North-West Power Pool and is concerned with co-ordinating the operation of the various plants and so securing the maximum overall efficiency from the resources available.

From page 47

V. These transformers are oil filled and air cooled.

Direct current for circuit-breaker operation and similar duties is provided by a 72 cell Edison battery.

Reserve auxiliary power is available from a diesel-alternator set consisting of a Cantieri Navali Riuniti Ancona 100 h.p. 500 r.p.m. four-cylinder engine coupled to a Tecnomasio Brown Boveri 220 V 50 cycle three-phase generator.

The information contained in this article, and the accompanying illustrations, have been kindly placed at our disposal by Società Imprese Centro Italia.

Central Mixing Plants. Three leaflets have been received from Blaw Knox Limited giving particulars of circular central mixing plants of 600 and 400 cu. yard, 200 and 140 cu. yard, and 90 and 60 cu. yard capacities respectively. The leaflets constitute an advance issue of material that will appear in a comprehensive catalogue covering the complete range of Blaw Knox "Batcherplants," including circular and rectangular types of central mixing and batching plants, plants for ready-mixed concrete, materials handling equipment, and so forth.

An Indian Tour

A few notes on hydro-electric developments in India are given by John Warnock, who recently inspected some of the projects in that country.

THE Mahathma Gandi Hydro-Electric Station is situated on River Sharavathi, in Mysore State, a short distance downstream of the Jog Falls. It is fed from a large storage reservoir on the river formed by the Hirebhasgar Dam, whose special feature is the volute siphons to which reference was made in the April 1951 issue of WATER POWER*. The end siphon of the range is illustrated in Fig. 1, occupying a prominent position in front of the dam structure, and a close-up view of the air inlets is shown in Fig. 2. These siphons which form the principal spillway feature of the dam are eleven in number, of which ten are 18 ft. diameter and one 16 ft. in diameter, the whole being designed to discharge 250,000 cu. ft. of water per second. The siphons are automatic in operation, their design having been based on model experiments which were carried out at one of the hydraulic research stations in India.

As a matter of interest, it might be stated that the hydraulic research stations carry out important investigations into all kinds of water flow and other problems connected with river and harbour work as well as irrigation and hydro-power researches. The earliest research station was laid down at Poona in 1920. One is located at Bhadrabad, on the Upper Ganga Canal, near Hardwar, in United Provinces and alongside the station is Bhadrabad Power Station shown in Fig. 3. This small power plant operates on a small fall of 15 to 19 ft. on the canal, to generate 4,400 kW through six small generating sets.

The Ganga Canal was constructed about one hundred years ago and feeds an irrigation project from the river Ganges at the Mayapur Head Works, near the ancient city of Hardwar. It has a capacity of about 8,000 cusecs but when the river is at its lowest level between February and March the discharge diminishes to about 5,000 cusecs. This small station runs in conjunction with several other stations and the power is utilised over an area of some 10,000 sq. miles for domestic purposes, and for irrigation pumping from canals and tube wells.

The Tungabhadra Dam

The Tungabhadra dam is a joint project that is being undertaken by the States of Madras and Hyderabad and is mainly an irrigation scheme to water an area of about 2 million acres along the Tungabhadra river, which forms the boundary between the two States. This part of India suffers periodically from deficient rainfall, and the irrigation water made available by the scheme will enable rice, cotton, sugar cane, millets etc. to be grown in greatly increased quantities. The dam is being built across the broad bed of the river, which is a tributary of the Krishna and has a drainage area, upstream of the dam, of over 10,000 sq. miles. The reservoir will cover about 133 sq. miles and will afford storage for some 2·6 million acre ft. The design is such that it will be possible to increase the height 5 ft. at a later date. It is a masonry structure and is of the gravity type built of random granite rock, with a maximum height over the deepest foundation of 160 ft. Dressed stone is used on spillway buckets and for quoin work generally, and the dam faces are being built in coursed masonry securely keyed into the interior rubble masonry.

The spillway section, of the ogee type, is 2,300 ft. long and is arranged with a break velocity bucket along the base. Normal sections on either side of the spillway extend to a total length of 3,642 ft. Two further dams on the Hyderabad side are to be built

*"The Fourth Congress on High Dams," April 1951, p. 143.

Fig. 1. Hirebhasgar reservoir on river Sharavathi, showing dam with volute siphons in front

Fig. 2. Hirebhasgar dam showing air inlets for depriming the siphon

Fig. 3. Bhadrabad power station on upper Ganga Canal near Roorkee

Fig. 4. Excavation for Tungabhadra dam showing masonry dam structure with main drainage gallery

across depressions in the local terrain, one of the earth fill type and the other of composite concrete-earth construction.

The spillway section of the dam is being built in cement mortar mainly 1 : 4 mix with a 20 per cent. admixture of surki, a ground clay brick material. On the front 9 ft. of the structure the cement-mortar mix is 1 : 2¼ in order to obtain greater watertightness. The non-spillway portions are being built with a lime-surki-sand mortar in proportions 1 : 1 : 1, excepting where sluice and pipe blocks occur in the structure. At these points red cement mortar 1: 4 to 1 : 5 mix is used. Construction joints are incorporated on cement-mortar built sections generally arranged at 93 ft. 4 in. centres, and also at sluice and pipe blocks on the non-spillway section. Copper sealing strips are arranged upstream and downstream at these joints. No construction jointing is allowed for in the lime-mortar built sections of this dam, this being the usual practice with lime-built masonry work on dams.

A drainage gallery 5 ft. wide and 7½ ft. high runs through the body of the dam about 10 ft. above the rock foundation level and some 15 ft. from the front face of the dam. Pressure relief holes, spaced about 20 ft. centres and 4 in. in diameter, are drilled from the gallery into the rock foundation, and porous concrete pipes, 8 in. internal bore, are built vertically into the dam at intervals of 23 ft. These porous pipes are intended to collect any leakage which may occur from the face of the dam into the drainage gallery which has suitable outlet arrangements for the discharge.

Along the spillway, 33 lift-type steel crest gates, each 60 ft. long by 15 ft. in height, will be arranged to control floods. The designed total maximum discharge capacity of these gates is about 650,000 cusecs.

For irrigation purposes, a canal on the left bank and one on the right bank are being built as supply feeders from the artificial lake to be formed, and are designed for discharges of 7,000 and 2,500 cusecs respectively. The larger canal, on the Hyderabad side, will irrigate over a million acres, while the other will serve a somewhat larger area in Madras.

Power generation to the extent of 48,000 kW will be provided for Madras in two stations, one at the dam and a further one some distance along the main canal. For Hyderabad, a power station will also be located at the dam and there will be four further stations downstream having a designed total capacity of 110,000 kW.

Fig. 5. River bypass under construction for Tungabhadra dam

Fig. 6. Tungabhadra dam spillway section

Such dual schemes as these are very necessary for India where there is an urgent need to grow additional food for the rapidly increasing population and to also provide an alternative form of heat to the present domestic cooking arrangements which consume dung that would be of great value in increasing the crop yield.

Konar Dam

The Konar dam project is one of a series of works in the valley of the river Damodar in the State of

Fig. 7. Contraction joint and porous drainage duct in structure of Tungabhadra dam

Fig. 8. Another view of Tungabhadra dam under construction

Fig. 9. Model of Konar dam for the Damodar Valley project

Bihar, north west of Calcutta, which has been undertaken to control the severe flooding that occurs in the monsoon period and to provide irrigation for the raising of grain and other crops. Arrangements are also in hand to generate electricity both from hydro and steam stations, the latter deriving their fuel from nearby coal reserves. Rainfall occurs in this region from June to October and averages 54 in. per annum.

The general development of the valley is being carried out somewhat on T.V.A. lines, involving land reclamation, the arrest of soil erosion, irrigation, and the development of hydro power; education of the agricultural population on proper methods of tillage is also in hand. Eight main storage reservoirs are to be constructed for irrigation purposes and to serve hydro stations having a total projected capacity of some 240,000 kW. In addition, a thermal plant of 200,000 kW is now under construction at Bokara. This latter plant, which is provided with American equipment, is now almost complete.

The Konar Dam, of which a model is shown in Fig. 9, is now in the early stages of construction. It is situated on the Konar River, a tributary of the Bokara which is itself a tributary of the Damodar River. It is essentially an earth dam, having a total length of over 12,000 ft., with a concrete spillway section about 900 ft. long and about 157 ft. maximum height above the river bed. The spillway is designed to discharge 250,000 cusecs over its crest from a total drainage area of 385 sq. miles. A hydro plant of 20,000 kW will be associated with the reservoir and a further purpose of this storage is to provide cooling water for the Bokara thermal station, situated a short distance downstream.

Irrigation for the raising of food crops is a very

(Continued on page 61)

Fig. 10. Penstock valve house for Bhira power station showing additional penstock being installed

Fig. 11. General view of Bhira power station and pipelines

Water Power in Africa

G. H. Lepper, A.M.I.E.E., surveys the hydro-electric potentialities of this continent.

ALTHOUGH it has been estimated by Professor H. K. Barrow, the well known American consulting engineer on water power development, that the African continent contains about 275 million h.p. of potential water power—more than 40 per cent. of the potential water power of the entire world—probably less than a quarter of a million horse-power has yet been developed in the whole of Africa. There are indications that a new era is dawning. Projects comparable in size with the great installations of North America are being studied and, if the financial difficulties presented by the high initial cost of large scale hydro-electric schemes can be overcome, a great change will come over the scene during the next quarter of a century. The need for rapidly increasing Africa's production of foodstuffs and essential materials to meet the growing requirements of its own expanding population and those of the great industrial countries of the world is turning attention more and more towards African development. Mining and secondary industries, even agriculture, all need power. Apart from a comparatively small region in the south and still smaller areas in the west and extreme north there are no local resources of coal, and imported supplies are very expensive and often difficult to obtain. Oil has so far only been found in Egypt. Consequently over the greater part of Africa, once a demand for electric energy arises, there are compelling reasons for investigating possible sites for hydro-electric installations.

In the extreme north and the far south of the continent the low rainfall and the physical conditions do not afford very much scope for large scale exploitation of water power. Both the Atlas and the Drakensberg mountains are deficient in this respect and although the Orange River, with the Vaal and other tributaries may eventually be harnessed to produce a substantial quantity of power the cost of developing it would be too high to make the idea attractive so long as Transvaal coal is obtainable at anything like its present cost. Although the Aughrabies Falls on the Orange River, about 300 miles west of Kimberley, are among the great falls of the world, their remoteness from any large consuming centres and the great variation in flow between wet and dry seasons do not encourage efforts to turn them to account.

Where potential water power exists in vast quantities, as in the basins of the Congo, Nile, Niger and Zambezi, it also has hitherto been too distant from important centres of consumption to be worth bothering about, except to an almost negligible extent. It is true that in the Belgian Congo some moderate-sized hydro-electric plants have been installed but their total capacity is only a fractional part of the 130 million horse-power which it is believed could be obtained by full development of the possible sites on the main stream of the Congo and its tributaries; indeed, nearly half the total water power resources of Africa and about a fifth of those of the whole world are to be found in the Congo basin alone. In the two main steps of the drop of the lower Congo river through the Crystal Mountains, between Stanley Pool and the estuary, where there is a total descent of about 900 ft. in 150 miles, the potential amount of power available is put at something like 100 million horse-power; utilisation of a small part of this enormous flow of energy is planned to supply electricity for operating the steep railway line between Matadi and Leopoldville. In the middle Congo the rapids above Stanleyville might be made to produce another 10 to 15 million horse-power but the engineering difficulties would be greater and no very large demand for power is to be expected in this region in the near future.

French Equatorial Africa, which shares the Congo basin with Belgium, and French Cameroon also possess very extensive water-power resources, possibly amounting to a potential of 50 million horse-power; part of this large amount is contributed by the important rivers which flow directly to the Atlantic through Gabon and Cameroon; at the Edea Falls on the Nyong River about 50 miles inland from Duala work has been begun on the first stage (30,000 kilowatts) of a hydro-electric plant with a transmission line to Duala. This is the largest scheme of the kind to be begun in French Africa.

In Nigeria, through which flow the lower Niger with its principal tributary the Benue, the potential water power available may amount to 13 million horse-power but so far the only important exploitation that has taken place is on side streams of the Benue on the Bauchi plateau where the Nigerian Electricity Supply Corporation has several hydro-electric plants with an aggregate installed capacity in kilowatts running into five figures. These stations supply energy to the tin-mining district. In the upper reaches of the Niger the French plan to utilise the Sotuba rapids to supply power to Bamako.

In Portuguese Africa there are several projects for developing power from the Cunene, Cuanza and Catumbela rivers in Angola and from the Sabie-Incomati and Movene rivers in Mozambique. Of these the largest is a scheme for installing 47,000 kilowatts at the Duke of Braganza falls on the Lucala tributary of the Cuanza.

The principal hydro-electric undertakings actually in operation in British Africa other than Nigeria are to be found in Northern Rhodesia, Kenya and Tanganyika; there are a few minor installations in the eastern Transvaal, Southern Rhodesia and Nyasaland. In Northern Rhodesia the Mulungushi and Lusenfwa plants on tributaries of the Luangwa are comparable in size with those in Nigeria and British East Africa; the energy generated goes to the Broken Hill mines. At the Victoria Falls there is a small plant to supply current to Livingstone and the Victoria Falls station and hotel. The East African Power and Light Company has stations on the Tana river, supplying the Nairobi district of Kenya, and on the Pangani river,

in Tanganyika, to provide power for the sisal estates near Korogwe and other users in this region. Both the Tana and the Pangani flow directly into the Indian Ocean and do not therefore belong to any of the four major river basins of Africa. All the developments hitherto mentioned are relatively small fry, valuable as their contribution has been to the economic progress of the localities in which they are situated, and they will be dwarfed by the schemes of the first magnitude which are now beginning to come into view. One of these, at Owen Falls, Uganda, on the Victoria Nile, is already under construction. It will have an ultimate capacity of more than 100,000 kilowatts and the cost in sterling will run into eight figures. It is expected to provide Uganda with very cheap power and to facilitate the agricultural, mining and industrial development of the southern half of the Protectorate; some of the power may be sold in the western part of Kenya. There are other possible sites for extensive power development in Uganda, such as the Murchison Falls near Lake Albert and along the Semliki river.

Much further north in the region of the Nile cataracts although immense quantities of potential energy are going to waste there does not seem to be much likelihood of sufficient demand for power arising south of Aswân to warrant the construction of large hydro-electric plants in this region. At Aswân, where the necessary storage and head have already been created by the great dam built to control the Nile floods, the position is entirely different. The Aswân dam hydro-electric project will generate upwards of a quarter of a million kilowatts for eight months of the year but only about a fifth of this quantity during the remaining four unless the variation in the available head is smoothed out to some extent by the construction of subsidiary plants at the Esna, Nag Hamadi and Asyut barrages and possibly also at Wadi Halfa. The idea is to transmit the "firm" (all the year round) output to Cairo and the Delta by a 275 kV transmission line and to utilise the extra amount, which will only be available for part of the year, for the manufacture of fertilisers and possibly for electro-metallurgical processes.

Along the main stream of the Zambezi one of the largest hydro-electric projects yet conceived in the Eastern Hemisphere has recently been the subject of an expert report which describes it as having exceptionally favourable characteristics. Until recently, when power development on the Zambezi was mooted, thoughts turned naturally to the Victoria Falls, that great southern rival of Niagara, where in the early part of the century the idea of generating power and transmitting it to the Witwatersrand was seriously considered. At that time the technical difficulties of transmitting energy for a distance of something like 600 miles over a route passing through almost uninhabited country were regarded as too formidable and the existence of cheap coal in the Johannesburg district was an additional reason for abandoning the idea. More accurate knowledge of the characteristics of the site and of the tremendous variations in river flow between dry and flood seasons, with the impracticability of regulating the flow above the Victoria Falls by storage works, have further weakened enthusiasm for harnessing these falls on any great scale; indeed it would hardly be possible to install a power station at the falls themselves to supply very large quantities of firm power throughout the year without ruining their appearance in the dry season. From the power producing point of view the Victoria Falls are nothing like Niagara, which has the vast storage basins of the great North American lakes to act as flow regulators. Fortunately, there are other and better sites lower down the river, one such being at the lower end of the zigzag Batoka gorge, some 40 miles long, in which the river drops more than 1,000 feet in altitude. Some 200 miles nearer the mouth, the Zambezi passes through the Kariba Gorge, rather more than 16 miles long but with little fall in altitude. Here, only half the distance of the Victoria Falls from the principal energy consuming centres of Southern and Northern Rhodesia, there is a very favourable site for the construction of a dam comparable in size with some of the great American dams. It would be nearly 400 ft. high above the river bed and nearly a quarter of a mile long, forming a lake with an area of about a million acres if the most favourable site near the lower end of the gorge proves on further examination to provide the necessary rock conditions for safe anchorage of the structure. The proposed initial development of about 385,000 kilowatts is estimated to cost £43½ millions at the prices ruling late in 1950 and the full development of about a million kilowatts would, on the same basis cost nearly £75 million. Transmission lines operating at 220 kilovolts would convey energy to the Northern Rhodesian copper belt (260 miles) and to points on the railway between Gatooma and Salisbury (175 miles). It is believed that power could be delivered there in bulk at very much lower rates than the probable cost of energy generated in steam or oil stations ten years hence, when the Kariba scheme might be expected to come into operation if begun without delay. When the full development at Kariba ceases to be adequate for the needs of the areas to be supplied there is another site at the Kafue Gorge, about 50 miles to the north, where, by building a storage dam at the upper end and taking water to power stations at the middle and lower ends of the gorge, a further 380,000 kilowatts could be developed; the Kariba and Kafue gorge stations together should be capable of meeting requirements for many years.

Another large-scale project in the Zambezi basin relates to the regulation of Lake Nyasa and the Shiré river by which the lake discharges into the Zambezi. It is understood that investigations recently carried out have indicated that it would be practicable to construct a dam near the southern end of Lake Nyasa and so prevent both the wide fluctuations in lake level which occur over a long period and the serious Shiré floods. Given regulation of the river flow the installation of a power station to utilise the head available at the Murchison cataracts would be feasible; a source of cheap power would stimulate industrial development in Nyasaland. Although not so great as that of the Kariba Gorge scheme the Nyasa-Shiré works would be a major undertaking which would probably cost at least £10 m. and could only be financed by Nyasaland with extensive outside help.

In West Africa an even more costly project than the Kariba Gorge scheme is now being studied. The power development possibilities of the Volta River in the Gold Coast have been investigated with a view to the irrigation of an extensive area and the production of aluminium from local bauxite ore. As to the cost.

(Continued on page 64)

Hydro-Electric Resources of Belgium and the Belgian Congo

By L. de Heem, Ingénieur Mécanicien-électricien,
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As Belgium has important resources of solid fuel, most of her electrical energy demands are supplied from thermal installations: the hydraulic resources capable of being developed are very slender. The situation in the Belgian Congo is, however, entirely different. With a hydrographic basin covering 1,388,308 sq. miles, watered over its whole area by abundant rains, the colony represents one of the richest reserves of hydraulic energy in the world.

In Belgium, the only hydro-electric plants of any importance in service are grouped in the valleys of the Warche and Amblève rivers. They include the storage plants of Butgenbach and Bévercé, whose installed capacities are of 1,850 kW and 11,550 kW respectively. The latter installation uses a head of 505 feet, the highest possible obtainable in Belgium. A plant using the flow of the Amblève and having 9,000 kW of installed capacity is situated at Heid de Goreux.

Taking into account seven small local plants whose individual capacities vary between 100 and 400 kW, and of which five are situated outside the basin of these two streams, the total installed hydro-electric capacity at the present moment amounts to 23,000 kW, of which 19,500 kW are connected to the 150 kV general network.

There remain, however, other hydraulic resources as yet unharnessed, notably the Meuse (between Namur and the Dutch frontier), and the Ourthe. The Meuse offers the most interesting projects for the immediate future. Two circumstances render them favourable: a high utilisation of the installed capacity (of the order of 4,000 or 5,000 hours per year), and the fact that capital outlay would be limited in most cases to the electro-mechanical equipment, the construction of weirs being in any case necessary to regulate the flow.

A project for the Meuse could provide five hydro-electric stations having a total capacity of 40,000 kW, of which three would be above Liège and two below. These plants could never guarantee more than a relatively low figure of firm kilowatts, seeing that the

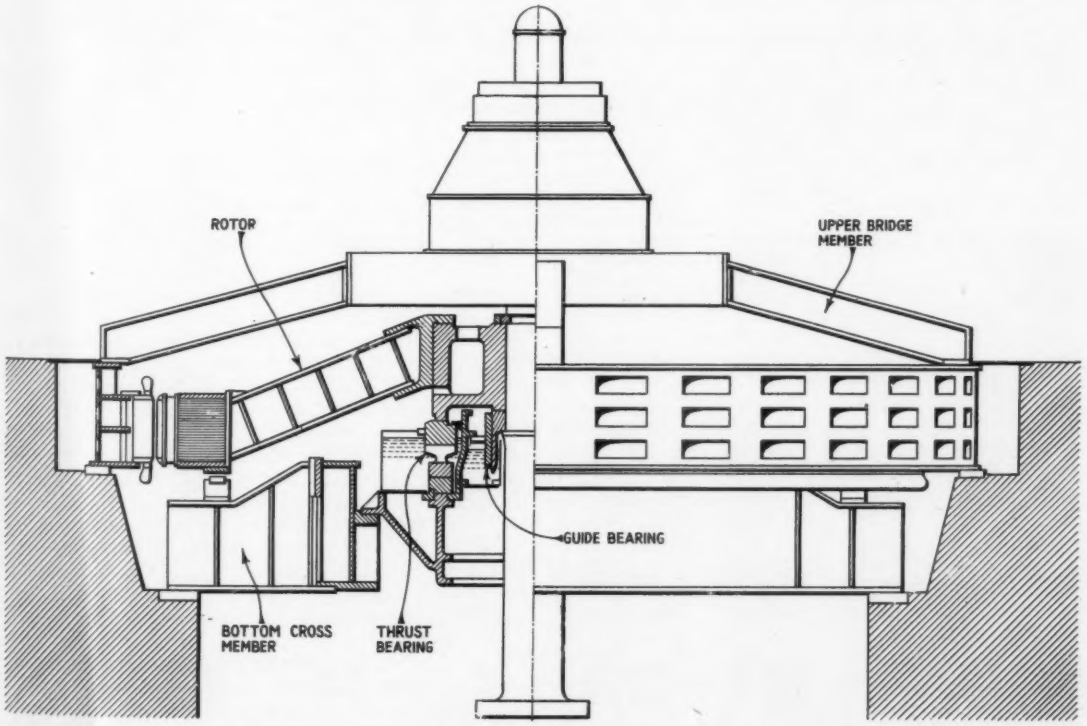


Fig. 1. Section through an A.C.E.C. alternator showing the umbrella type of construction

flow of the river is variable throughout the year.

Two stations of 8,250 kW and 16,000 kW are under construction at Yvoz-Ramet and Monsin respectively. They will each have a head of from 13 to 16 ft. and are expected to be in service in 1953.

For the development of the Ourthe, dams would have to be built of which one would reach a height of 213 ft. Capital charges would seriously endanger the cost per kWh, especially as the plants would have the low utilisation factor of 2,500 hours per year. Only by using the dams for other purposes such as the regularising of the flow in the lower reaches of the Ourthe and Meuse, or for the accumulation of reserves of town water, could the project be made economically feasible.

Table I gives a survey of the hydraulic resources in Belgium capable of being economically exploited. The guaranteed values would be relatively low, Belgium being able to count on only a very variable atmospheric precipitation.

The complete development of the above hydraulic resources would cause an economy in coal consumption of less than 1 per cent. of the total prewar production of our coal mines. Hydro-electric production, although not negligible, can only be considered as a very partial solution to the problem of ever increasing demand.

TABLE I—HYDRO-ELECTRIC RESOURCES OF BELGIUM

Plants	Installed Capacity kW	Average output 10^6 kWh
Existing		
Warche and Amblève power stations	21,710	56
Local plants	1,365	1
	23,075	57
Under Construction		
On the Meuse at Monshin ...	16,000	64
Yvoz-Ramet ...	8,250	40
	24,250	104
Projected		
On the Meuse		
Lanaye	5,000	25
Other plants	40,000	220
	45,000	245
On the Ourthe		
Laroche	45,100	84
Barvaux	7,300	40
Esneux	3,000	15
	55,400	139
Total projects economically realizable	147,725	545

Belgian Congo

In the Belgian Congo, the exploitation of possible hydro-electric sites has scarcely begun. Moreover, such is the scope of the problem that a precise estimate of the energy available has not yet been made.

An estimate based on a trial inventory made in 1945* gives the natural hydraulic capacity available as being of the order of 120 million kW of which some 10 million kW could be exploited economically.

Table II, taken from a paper published in 1947 on the occasion of the Association of Engineers, graduates of Liège University (A.I.Lg) Congress† gives an idea of the principal resources capable of being harnessed. They represent about 4,800,000 kW. All these values are approximate, being based for the most part on very unprecise data.

*M. R. A. Bette, "Resources hydrauliques du Congo" Bulletin of the "Institut Royal Colonial No. XVI, 1945."

†M. M. J. Strauven, "Forces hydrauliques du Congo Belge," Congrés de l'A.I.Lg, Section Coloniale.

TABLE II—HYDRO-ELECTRIC RESOURCES IN THE BELGIAN CONGO

Water course	Flow low water (gals./min.)	Annual average flow (gals./min.)	Fall in feet	Low water	Power Natural Average	(10^6 kW) Recoverable
		Lower Congo				
Congo	333,000,000	519,480,000	925	58·6	87·9	1·400
Inkisi	799,200	1,998,000	787	0·12	0·30	0·230
Kwilu	333,000	799,200	131	0·008	0·019	0·012
M'Pozo	133,200	466,200	197	0·005	0·017	0·012
						1·654
		South Katanga				
Lualaba	372,960	1,278,720	1,496	0·102	0·365	0·120
Lufira				0·026	0·104	0·104
Luapula	799,200	5,328,000	49	0·007	0·048	0·039
Lubudi	532,800	1,998,000	164	0·016	0·060	0·036
Kalule Nord	66,500	226,440	1,558	0·013	0·043	0·030
Kalule Sud	66,600	226,440	1,377	0·011	0·038	0·027
Kando	26,640	93,240	328	0·002	0·006	0·004
Numerous small streams	66,600	266,400	410	0·050	0·200	0·060
						0·420
		North Katanga				
Luvua	1,332,000 to 2,530,800	3,996,000 to 7,459,200	321	0·105	0·310	0·172
		Kwango-Kasai				
West of the Loenge ...	7,990,000	23,976,000	656	0·960	2·870	2·150
East of the Loenge ...	9,990,000	31,302,000	328	0·600	1·880	0·376
						2·526
					GRAND TOTAL	4·772

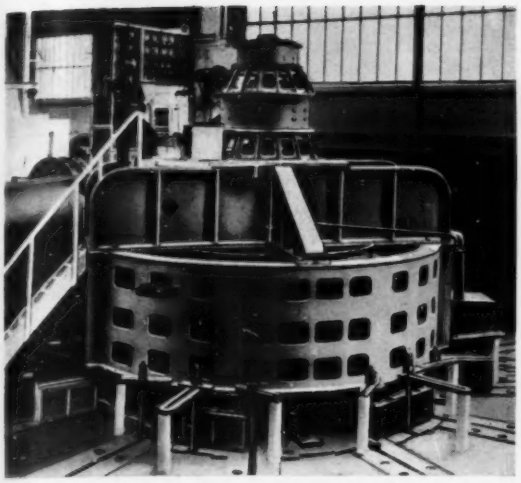


Fig. 2. A.C.E.C. 15,600 kVA 333 r.p.m. vertical alternator

The rapids region between Leopoldville and Matadi, in the lower reaches of the Congo river, is the most important site in the colony. The extreme regularity of flow of the river, whose minimum flow of about 333,000,000 gallons per minute compares with an annual average of about 519,480,000 gallons per minute, is explained by the compensation of rainfall between places on each side of the equator, the rainy seasons in the north coinciding with dry periods in the south and vice versa.

The energy in the lower reaches, were it possible to harness it completely, would alone represent the half of the total energy of the whole Congo basin. But the relatively small fall, the large quantities of water to be dealt with and the extreme width of the valley make it doubtful if the whole of this power can ever be economically harnessed.

It has been calculated that the power technically capable of being exploited would be of the order of 1,500,000 kW—scarcely 1·7 per cent. of the natural resources. This figure is nevertheless considerable, being of the same order as the capacity of the biggest stations built in the United States.

The tributaries of the lower Congo, notably the river Inkisi, are also rich in hydraulic resources. The rivers Lualaba and Lufira in the south of the Katanga Province are to be specially noted, as well as the Luvua in the north Katanga and the streams to the west of the river Loenge in the Kwango-Kasai Province.

Approximately 115,000 kW of plant is already installed, the figure being a little more than 1 per cent. of the total reserves economically available. The principal plants are those on the Cornet falls (64,000 kW), the Piana Mwanga rapids (15,000 kW), the Koni rapids (45,000 kW), the Sanga falls (12,500 kW), and the Budana falls (7,000 kW). A large station, of 120,000 kW capacity, is under construction at N'Zilo.

Belgian Manufacturing Capacity

Belgian mechanical and electrical construction industries are capable of supplying all the machines and apparatus necessary to equip the hydro-electric plants, excepting the hydraulic turbines, for which there exists in Belgium no factory specialising in their construction.

The design of alternators for hydro-electric plants, which have been produced in Belgium, include the following general trends. Rotors are generally composed of a shaft carrying a cast-steel hub on to which thick discs are built up by a hot process. The periphery of these discs is grooved to allow the fixing of the pole pieces. The stator is made up of a shell of welded sheet iron. In this are built up the laminations which are cut out to receive the windings.

To economise in the height of vertical alternators, the upper shaft bearing is combined with the thrust bearing. When the size and weight of the machines prohibits their being assembled in the factory, the rotor is built up on the site. This type of rotor consists of a cast-steel hub to which are fixed the centring arms for the rim. The rim is made up of bands of shaped thin sheet iron overlapping at their extremities and clamped vertically between strong jaws. The rim segments are notched so as to receive the pole pieces and allow the assembly of these without the need for further adjustment.

In this category of machine, when the diameter of the stator becomes abnormally large, e.g. above 23 ft., the so-called "umbrella" type of construction is used. In this the pole wheel is held by a single bearing placed under the rotor, and by the turbine shaft bearing. The thrust bearing is mounted on the bottom cross member whose span is less than that of the upper bridge member. Fig. 1 shows the type of construction used in the alternators for the Meuse hydro-electric stations, and Fig. 2 shows an example of a 15,600 kVA 333 r.p.m. alternator for the Congo.

From page 56

urgent problem in the State of Bihar, parts of which have recently been threatened with famine conditions. It is proposed to irrigate about one million acres under the present development schemes, making use of stored water from pondages and led through associated canals and distributors having total length of over 1,500 miles.

The Tata Plants

The three Tata hydro-electric power stations situated in the Western Ghats to the south-east of Bombay, and from 40 to 60 miles distant from the City, are at Bhivpuri, Khopoli and Bhira, with generating capacities of 65, 69 and 110 MW respectively. These stations supply practically all the needs of the City of Bombay. They operate on heads ranging between 1,600 to 1,700 ft. derived from high level storage reservoirs formed in the Western Ghats to collect the monsoon rains which occur for three to four months between June and September each year.

In the Bhira station (Fig. 11) the present plant consists of five Pelton-wheel sets of 22,000 kW, but a sixth Pelton-driven turbo-alternator is now being installed. This addition has involved the erection of a further pressure pipe, a view of which is given in Fig. 10. This view also shows the valve house on the higher ground adjacent to the termination of the tunnel, which forms the upper link of the conduit conveying pressure water from the storage lake. The existing upper pipes from the tunnel are duplicated on the lower slopes to the power station as will be noted from Fig. 11.

New Power Developments at Niagara Falls

By J. J. Traill, Hydraulic Engineer, Generation Department, The Hydro-Electric Power Commission of Ontario, Canada.

THE Niagara Treaty of 1950 has opened the way for further utilisation of the power resources of the Niagara river in both Canada and the United States. On the Canadian side, it has enabled the Hydro-Electric Power Commission of Ontario to undertake the biggest single power development in its history. When completed this project will provide a new resource of 1,200,000 h.p.

The new Treaty supersedes certain clauses in the Boundary Waters Treaty of 1909-10, which limits the daily diversion for power development to 36,000 cusecs in Canada and to 20,000 cusecs in the United States. The requirements of additional power for defence purposes during the war resulted in permission for temporary additional diversions amounting to, in all, 19,500 cusecs in Canada and 12,500 cusecs in the United States, these amounts being sufficient to enable all existing installations to operate continuously at their full capacity.

Niagara Treaty of 1950

The possibility of using more water for power development has been the subject of study by governmental and other agencies for many years, the preservation of the scenic value of the Falls and Rapids being given a high place. The Treaty of 1950, therefore, has fixed the minimum flow that must be permitted to pass over the Falls and through the Rapids, and allows all additional flows in the river above this minimum requirement to be used for generation of power.

The Treaty requires that during daylight hours in the tourist season (that is, from the first of April until the end of October), 100,000 cusecs must be allowed to pass over the Falls, and at all other times a minimum of 50,000 cusecs. There is, of course, a great variation in the spectacle due to natural variation in flow in the river and, to maintain the scenic values, and possibly at times to improve them, remedial works are envisaged, designed to distribute the flow satisfactorily over the whole of the crest.

Article 2 of the Treaty provides for the appointment of an International Board to study and report upon remedial measures and this Board is now actively engaged upon this problem. It is anticipated that with the completion of the works, which will be outlined by the Board, the whole crest of the Falls will be clothed with a falling sheet of water through-

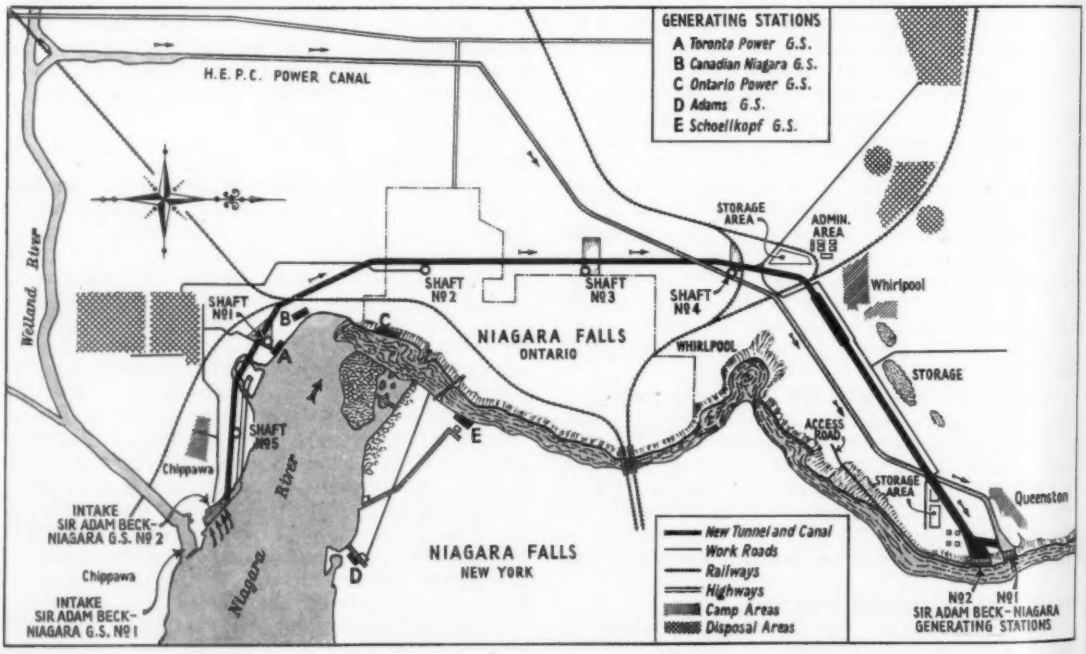


Fig. 1. Key plan of the Niagara area showing the new power project under construction by The Hydro-Electric Power Commission of Ontario

Fig. 2. Model of Niagara Falls and upper Niagara river, to assist engineers to determine a suitable location for the intake of the Sir Adam Beck No. 2 generating station

out the daylight hours of the tourist season; further, the bare flanks visible in periods of low flow will no longer be exposed.

Models Constructed

A problem such as this is quite evidently best investigated by means of experiments. Two organisations, one in each country, acting in co-operation with the International Niagara Board, have built models of portions of the river, including the Upper Rapids and the Falls themselves, and experimental work is being vigorously prosecuted on these to obtain a solution to this very complex problem. In Canada, the Hydro-Electric Power Commission of Ontario has built a model of the river (extending from Grand Island to a point immediately below the Falls) on a scale of 1 to 250 horizontally and 1 to 50 vertically. The United States Army Engineers have built and are using a model on a somewhat smaller scale but covering the whole length of the river from Lake Erie to a point immediately below the Falls. This model is on a scale of 1 to 360 horizontally and 1 to 60 vertically. In addition to the investigation of necessary remedial measures, the models are being used for the solution of various other problems related to the generation of power.

Niagara River Power Development

Early development at Niagara Falls on a major scale, commencing in 1894 and continuing until 1917, made use of the head available only in the immediate vicinity of the Falls. During the period 1917-1930, the Hydro-Electric Power Commission of Ontario completed the construction of the Queenston development with a total installed capacity of 500,000 h.p., and in honour of the founder of Ontario Hydro this plant has been renamed The Sir Adam Beck—Niagara Generating Station No. 1. This project was designed to utilise as much as was feasible of the total fall available in the river. From the standpoint of conservation of natural resources, this was, and continues to be, an item of great importance. Some of the early developments on the river generated about 10 h.p. for each cusec diverted from the river, whereas the Queenston development generates over 29 h.p. per cusec. In view of the insistent demands for more electrical energy, this utilisation of the full head is manifestly of great importance. It is anticipated that eventually the less-efficient developments will be retired from service or will become standby plants to be used only in those periods when the water available, under the terms of the new Treaty, is more than sufficient to operate the new and more highly efficient plants that are projected.

The power developments at present operating at Niagara Falls have sufficient capacity to utilise more than the quantities of water divertible under the Treaty of 1909-10, and although additional diversions during the war years were permitted by international agreements, these were considered to be of a temporary nature and, in some cases, were so defined in the notes exchanged between the Governments. Under such conditions work could not proceed on new installations, but the Treaty of 1950 has now cleared up this difficulty and made construction possible.

Ontario Hydro's New Power Project

The problem of new works has been under study for many years by various organisations, and preliminary plans for an extension of its works had been prepared by The Hydro-Electric Power Commission of Ontario. As soon as the new Treaty was ratified the Commission was therefore in a position to proceed at once on a new project and work is now being vigorously prosecuted. It is probable also that, in the near future, work will commence on a similar high-head development on the United States side of the river.

The intake of the new project will be located on the shore of the river about 2,000 ft. downstream from the existing intake at Chippawa. Water will be conveyed from the intake through two pressure tunnels for a distance of 29,000 ft. Each tunnel will be 45 ft. in finished diameter, excavated in rock and lined with concrete, and in places will be over 300 ft. below the natural ground surface. At their termini the tunnels come to the surface, and through suitable transitions, merge into an open canal which continues for a distance of about 11,000 ft. to the forebay of the new plant. Penstocks, 19 ft. in diameter, lead to generating units in a power house located on the lower bank of the Niagara river immediately upstream from the

present power house. The new installation will be named The Sir Adam Beck — Niagara Generating Station No. 2.

Design of Intake

The style and design of the new intake structure have been investigated in the Niagara River model referred to above, and details are being worked out in a model of larger scale in the University of Toronto laboratory. In the investigations of the Niagara River model the functioning of the intake was studied under various water-level and ice conditions in the river, and a satisfactory and economical layout determined for the necessary excavation in the river channel in front of the intake. At times, very large quantities of ice pass down the river from Lake Erie, and it is imperative to assure that the intake will function without interruption under all river conditions.

Conduit and Tunnel

After the water passes through the intake it enters a short concrete-lined pressure conduit. Emergency control gates will be installed at the lower end of this conduit as a security measure and to enable the tunnel to be dewatered for inspection if this is found necessary. The profile of the conduit dips downward at an angle of 30 deg. to enter the tunnel portal, and the tunnel proper, excavated in rock, continues in this downward course to an invert elevation of 260, which is about 300 ft. below the level of the water in the river at the intake. After turning approximately horizontal the tunnel continues on a slightly rising grade so as to keep it within the limits of the favourable rock strata, which dip to the south. At the downstream end of the tunnel the elevation of the invert is 392. The tunnel then passes through a vertical curve with a deflection of 30 deg., then rising to emerge from the rock excavation and enter a transition from the circular to a 45 ft. square section, passing thence into the open canal.

The course of the tunnel for part of its length lies under the city of Niagara Falls, Ontario. One tunnel only will be constructed initially and contracts have been let for four sections totalling 24,900 ft. in length. Work is being actively pressed at the present time on the excavation of four of the five access shafts, which will be offset from the main bore in order that they may be used in the construction of the second tunnel.

When the Queenston plant was built an open canal was chosen as the most suitable channel for conveyance of water to that development, but in the intervening years the extension of the urban development around the city has proceeded beyond the canal and it is considered that an additional open channel would not now be suitable. The decision was made, therefore, to convey the water to the new plant by means of two tunnels which would not offer any interference with further surface activities in the district.

The Open Canal

Immediately downstream from the point where the tunnel emerges into the open there exists a prehistoric gorge filled to a great depth with glacial and other debris. The channel crossing this gorge will be trapezoidal in cross-section and concrete-lined, with a carrying capacity sufficient for the flow through the two new tunnels. The channel will have a bottom width of 94 ft. and side slopes of 2 horizontally to 1 vertically. Beyond the old river bed the trapezoidal section will change to a rectangular section where the rock strata are again at a high level. The section, 200 ft. in width with vertical sides but without lining, will continue to the forebay of the new plant. In its course it will meet and cross the present canal at the same level and a satisfactory design of this crossing was worked out after prolonged model investigations in the laboratory.

At the forebay of the new plant an ample connection will be made with the forebay of The Sir Adam Beck—Niagara Generating Station No. 1, so that flexibility in the use of water between the new and the old stations may be realised. The details of the design of the forebay and the interconnecting canal have also been worked out by means of model experiments.

The power house will contain twelve generating units, orders for six of which have been placed and a seventh authorised. The turbines will have a rated capacity of 105,000 b.h.p. each, under a head of 292 ft., and will operate at 150 r.p.m.; the generators are rated at 80,500 kVA, 13·8 kV, 60 cycles. Previous generation at Niagara Falls has been at 25 cycles, but a programme of conversion to 60 cycles is now in progress in Southern Ontario and new installations are designed for the higher frequency.

General

The work at present under way provides for a single tunnel with a capacity of approximately 20,000 cusecs, and a power house, as indicated above, containing, in the first stage, seven units with a capacity of approximately 100,000 electrical horsepower each. The ultimate development will involve the construction of a duplicate tunnel and the extension of the power house to contain twelve generating units. The first section of the development is expected to be in service in 1954 and thereafter it is proposed to clean out the old canal and repair the concrete lining, which has deteriorated to some extent in the 30 years of its lifetime.

From page 58

£105 million has been mentioned. An installation to generate more than half a million kilowatts is projected and the scheme involves the construction of a dam which would hold back the river for more than 200 miles. Most of the power would be used in the production of aluminium. Here again, however favourable the economic prospects may seem, finance is likely to present a serious obstacle. In this connection it has to be noted that the rise in prices which has occurred in the past year has already added a substantial amount to the probable cost of the Kariba project and there are no signs as yet of a reversal. The Treasury is said to be definitely hostile to the raising of capital for oversea undertakings of such magnitude and, in spite of the drawbacks, the Rhodesias, if they decide that it is essential to their economic development to go ahead with the Kariba scheme, may try to get the money elsewhere —which obviously means the United States. Now that the Gold Coast has obtained some measure of self-government that Colony also, if it wishes to proceed with the Volta project, may decide to seek American aid.

Design of Unlined Spiral Casings for Low-Head Stations

The author develops the theory of a cylinder of finite length strained by a moment at one end, and applies it to analyse the stresses in the generator support and the spiral casing. In a concluding article the loading on the floor is examined, and the complete stress analysis for the structure determined. Numerical examples apply the analysis to an actual case.

By DR. CHARLES JAEGER

General Nomenclature

τ_A = Total rotation at joint A.
τ_B ($= \tau^{xxx}$) = Total rotation at joint B.
τ_C ($= \tau^{x}$) = Total rotation at joint C.
τ_D ($= \tau^{xx}$) = Total rotation at joint D.
$\tau_{n\text{-}m}$ = Deflection of members n and m when a unit moment is applied at their junction.
T_n^z = Angular deflection in n_{th} member at point z.
$\tau_n^z = T_n^z$ for a unit moment applied at the same point.
τ^+ = Deflection at B considered as only part of slab DBC due to a moment at B.
α'_B, α'_C = Total deflection in BC at B and C when considered pin-jointed.
β_2 = Angular deflection of BC when isolated and pin-jointed $\left\{\begin{array}{l}\text{at } B \text{ due to unit moment applied at } C.\\ \text{,, } C \text{ ,, ,, ,, ,, ,, ,, } B.\end{array}\right.$
α_2 = As β_2 but at B due to unit moment applied at B.
δ_2 = ,, β_2 ,, ,, C ,, ,, ,, ,, ,, ,, C.
α_n^a = Total deflection from end to end of n^{th} member when considered pin-jointed and unit moment is applied at one end.
M = Bending moment.
M_n^z = General symbol for moment at n^{th} member at point z.
$A_{reinf.}$ = Cross-sectional area of beam occupied by steel reinforcement.
E = Young's modulus.
$E_{concrete}$, E_{steel} = Young's modulus for concrete or steel.
P = Shear force.
q, p_x = Load per unit length.
I = Moment of inertia.
$d\varphi$ = Angle of sector of spiral casing considered.
x = Distance along axis of a beam.
y = Deflection at any point on a beam.
σ = Stress.
s = Thickness or depth of section.
$R_{1,4}$ = Radius of outer wall AB of spiral casing, and generator support cylinder.
p = Water pressure.
$u = \sqrt[4]{\dfrac{3s^2}{R^2}}$
$\lambda = \dfrac{ul}{s}$
M^x, M^{xx}, M^{xxx}, $M^x{}_0$, $M^{xx}{}_0$ = Moment at joints C, D, B, G, H.
l = Length of beam.
E_1 = Effective Young modulus of reinforced concrete beam.
a = Distance along beam to point of zero bending moment.
$n = \dfrac{E_{steel}}{E_{concrete}}$
s_1 = Effective thickness of uncracked concrete + area of steel.
1, 2, 3, 4, 5, = Suffixes referring to A, B, . . .

THERE is no standard practice in the design and calculation of spiral casings. Much depends on the discharge and working head, on the type of set, on the general arrangement of the different floors and on how the static load, weights and hydraulic forces are transmitted to the foundation. A cast-steel or fabricated spiral casing involves problems which are quite different from those to be solved when dealing with unlined spirals.

In recent years a design has been developed for low-head vertical-shaft turbines where the main elements to be considered are an unlined spiral casing with an outside vertical wall which is nearly cylindrical and a cylindrical generator support. The weight of the turbine and generator, and the hydraulic forces are transmitted to the foundations through the generator support and the stay vanes, which have to be suitably anchored into the concrete.

There are many alternatives to this design according to the number of floors to be considered, to the thickness of the spiral wall and to the construction details of the stay vanes. In many cases the forces and moments to be transmitted to the reinforced-concrete structure are considerable.

The civil engineer will be concerned with the calculation and design of the reinforced-concrete structure, whereas the mechanical engineer will have to investigate the angular deflections and stresses to which the

stay vanes may be subjected.

Fig. 1 shows the spiral casing *ABCK* with stay vanes *GH*. From the point of view of stress analysis, the vertical outer wall of the spiral casing can be replaced over a short distance by a vertical cylinder *AB* with a radius R_1. The axis of this cylinder is identical with the axis *I–I* of the set under consideration. It is seen that calculations are made for the section with the biggest radial span along the centre line of the sets. Furthermore, it is assumed as the worst case that only one spiral casing is under water pressure.

The strains and stresses produced in this cylinder by the hydraulic pressure are transmitted to the foundations at *A*, and to the main floor *DBC* at *B*. Moments will be developed at *D* and *C* which will be transmitted to the cylinders *CE* (radius R_4, axis *I–I*) and *DF* (radius R_4, axis *II–II*). The cylinder *DF* supports the neighbouring turbo-generator unit. Similarly the load *p* acting on the floor *DBC* produces strains and moments which will be transmitted partly to the cylinder *AB* and partly to the cylinders *CE* and *DF*.

Moments and deflections caused by the two systems of loads will be calculated separately and then added.

The cylinder *AB* is therefore the fundamental element on which the design relies for safety, and should be calculated and reinforced accordingly. Before considering the deformation of the complete frame, it is first necessary to make an investigation into the behaviour of the cylinders *AB*, *CE* and *DF*, which are of finite length and under various end restraints.

1. General Theory of a Cylinder of Finite Length Strained by a Moment M^* at One End.

We shall consider (see Fig. 2) a cylinder of radius *R*, thickness *s* and length *l*. *E* is the modulus of elasticity of the cylinder, and *I* is the moment of inertia of the wall. *x* is the distance from any point *M* to the cylinder base, and *y* is the horizontal displacement of this point *M* when applying moments or forces to the cylinder. *M*, *P* and *q* are the bending moment, the shear force and the resultant radial load acting at the point *M*.

We can write the following equations for the cylinder wall:

$$EI\frac{d^2y}{dx^2} = M$$

$$EI\frac{d^3y}{dx^3} = \frac{dM}{dx} = P$$

$$EI\frac{d^4y}{dx^4} = \frac{dP}{dx} = q$$

We now consider an element of the cylinder of thickness *s*, unit height and length $Rd\varphi$ ($d\varphi$ being a small angle as shown in Fig. 2*a*). Assuming the cylinder to be thin, the tangential stress in the cylinder wall is

$$\sigma = \frac{yE}{R}\left(\text{with } y = \frac{\sigma R}{E}\right)$$

and the tangential forces are

$$\sigma s = \frac{ysE}{R}$$

which have a radial component

$$\sigma s\, d\varphi = \frac{ysE}{R}d\varphi$$

Now

$$I = \frac{1}{12}Rs^3 d\varphi$$

We assume that the internal pressure inside the

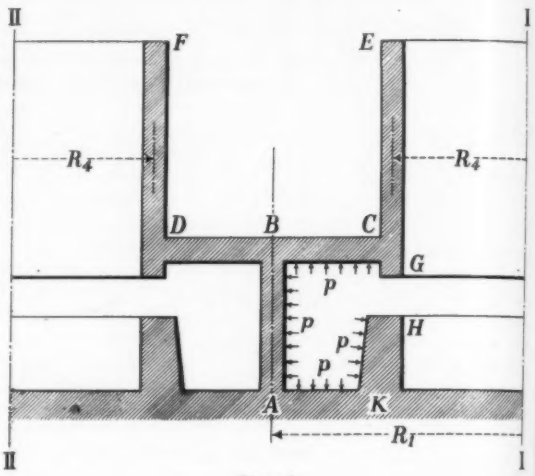


Fig. 1

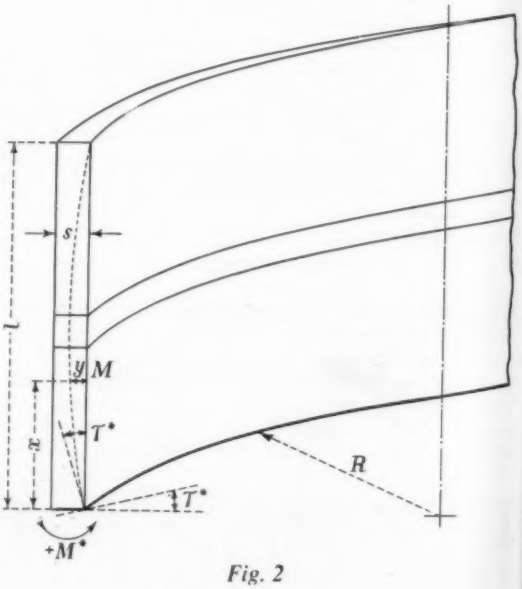


Fig. 2

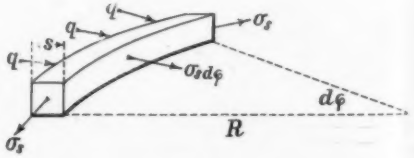


Fig. 2a

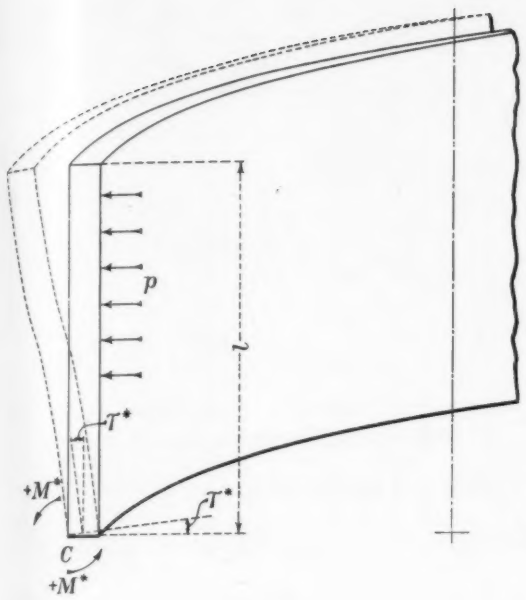


Fig. 3

cylinder is p. The radial load on the cylinder wall is then

$$q = \left(Rp - \frac{Eys}{R}\right)d\varphi = \frac{E}{12}Rs^3 d\varphi \frac{d^4y}{dx^4} \ldots\ldots (1)$$

And finally

$$\frac{d^4y}{dx^4} = -\frac{12y}{R^2s^2} + \frac{12p}{Es^3} \ldots\ldots\ldots (2)$$

This is the differential equation which we have to solve.

In these equations, we write q for a cylindrical element of unit height and length $Rd\varphi$; p, q and y are regarded as positive when directed outwards.

It is very easy to verify that the solution of equation (2) is of the type:

$$y = \frac{pR^2}{Es} + e^{\frac{-ux}{s}}\left(A_1 \cos\frac{ux}{s} + A_2 \sin\frac{ux}{s}\right) + e^{\frac{ux}{s}}\left(A_3 \cos\frac{ux}{s} + A_4 \sin\frac{ux}{s}\right) \ldots (3)$$

where $u = \sqrt[4]{3s^2/R^2} = 1{\cdot}316\sqrt{s/R}$.

The above equation is well known in the theory of elasticity and it also represents the deformation of beams resting on an elastic foundation. Note that Poisson's ratio μ and the effect $(1 - \mu^2)$ on the flexural rigidity of a homogeneous material have been neglected here, since the effect is small and, furthermore, uncertain for reinforced concrete.

The last equation clearly shows the superposition effect of the pressure p. Coefficients A_3 and A_4 would become zero if the cylinder were of infinite length.

By successive differentiation of equation (3) we obtain

$$\frac{s}{u}\frac{dy}{dx} = e^{\frac{-ux}{s}}\left[A_1\left(-\sin\frac{ux}{s} - \cos\frac{ux}{s}\right) + A_2\left(\cos\frac{ux}{s} - \sin\frac{ux}{s}\right)\right] + e^{\frac{ux}{s}}\left[A_3\left(-\sin\frac{ux}{s} + \cos\frac{ux}{s}\right) + A_4\left(\cos\frac{ux}{s} + \sin\frac{ux}{s}\right)\right] \ldots (4)$$

$$\frac{s^2}{u^2}\frac{d^2y}{dx^2} = 2e^{\frac{-ux}{s}}\left[A_1 \sin\frac{ux}{s} - A_2\cos\frac{ux}{s}\right] + 2e^{\frac{ux}{s}}\left[-A_3 \sin\frac{ux}{s} + A_4\cos\frac{ux}{s}\right] \ldots (5)$$

$$\frac{s^3}{u^3}\frac{d^3y}{dx^3} = 2e^{\frac{-ux}{s}}\left[A_1\left(\cos\frac{ux}{s} - \sin\frac{ux}{s}\right) + A_2\left(\cos\frac{ux}{s} + \sin\frac{ux}{s}\right)\right] + 2e^{\frac{ux}{s}}\left[-A_3\left(\cos\frac{ux}{s} + \sin\frac{ux}{s}\right) - A_4\left(\sin\frac{ux}{s} - \cos\frac{ux}{s}\right)\right] \ldots (6)$$

$$\frac{s^4}{u^4}\frac{d^4y}{dx^4} = 4e^{\frac{-ux}{s}}\left[-A_1\cos\frac{ux}{s} - A_2\sin\frac{ux}{s}\right] + 4\epsilon^{\frac{ux}{s}}\left[-A_3\cos\frac{ux}{s} - A_4\sin\frac{ux}{s}\right] \ldots (7)$$

Equation (1) is thus verified, since

$$\frac{s^4}{u^4}\frac{d^4y}{dx^4} = -4\left(y - \frac{pR^2}{Es}\right) \text{ and}$$

$$\frac{d^4y}{dx^4} = -\frac{4u^4}{s^4}y + \frac{4pR^2u^4}{Es^5} = -\frac{12y}{R^2s^2} + \frac{12p}{Es^3}$$

a) Application to Generator Support Cylinder *CE*

In this case there is no internal pressure p, and we shall consider a bending moment M^* uniformly distributed along the lower edge C of the cylinder (see Fig. 3). We will assume the radial displacement of this lower end is zero but that owing to the moment M^*, this edge undergoes an angular distortion τ^*.

Equation (2) reduces to $\frac{d^4y}{dx^4} = \frac{-12}{R^2s^2}y$ and the boundary conditions are:

$$\text{For } x = o : y = o\ ; \frac{dy}{dx} = \tau^*; EI\frac{d^2y}{dx^2} = M^*$$

$$\text{For } x = l: \frac{d^2y}{dx^2} = 0; \frac{d^3y}{dx^3} = 0,$$

the moment and the shear force at the upper end of the cylinder being both equal to zero.

For $x = 0$, the condition $y = 0$ gives

$$y = A_1 + A_3 = 0 \text{ and } A_1 = -A_3.$$

and the condition $\frac{dy}{dx} = \tau^*$ gives

$$-A_1 + A_2 + A_3 + A_4 = \frac{s}{u}\tau^*$$

$$\text{or } -2A_1 + A_2 + A_4 = \frac{s}{u}\tau^*$$

For $x = l$, we have to introduce an angle $\frac{ul}{s} = \lambda$ and to calculate the value of e^{λ}, $e^{-\lambda}$, cos λ and sin λ.

The two other equations at this point will yield the numerical values of the four constants A_1, A_2, A_3 and A_4.

Numerical Example.

Calculation of the concrete cylinder surrounding the generator support.

$l = l_4 = 3{\cdot}70$ metres, $R = R_4 = 4{\cdot}50$ metres,

$s = s_4 = 1{\cdot}50$ metres.

$$u = 1{\cdot}316\sqrt{\frac{s}{R}} = 0{\cdot}76$$

$$\lambda = \frac{ul}{s} = \frac{0{\cdot}76 \,.\, 3{\cdot}7}{1{\cdot}5} = 1{\cdot}865$$

$$= 1{\cdot}865 \,.\, \frac{180^\circ}{\pi} = 107^\circ$$

$\sin 107^\circ = 0{\cdot}956$ $\quad e^{\lambda} = 6{\cdot}488$

$\cos 107^\circ = -0{\cdot}292$ $\quad e^{-\lambda} = 0{\cdot}154$

The values of A_1, A_2, A_3 and A_4 are given by the four equations:

$$A_1 = -A_3$$
$$2A_1 = A_2 + A_4 - 1{\cdot}975\,\tau^*$$
$$6{\cdot}44A_2 + 2{\cdot}565A_4 = 12{\cdot}53\,\tau^*$$
$$4{\cdot}313A_2 - 12{\cdot}1A_4 = 8{\cdot}11\,\tau^*$$

the solution of which yields (in metres):

$$A_1 = -0{\cdot}006\,\tau^*$$
$$A_2 = 1{\cdot}935\,\tau^*$$
$$A_3 = 0{\cdot}006\,\tau^*$$
$$A_4 = 0{\cdot}028\,\tau^*$$

(All the figures in this paper are calculated with a slide rule only, and therefore are subject to some error.)

Relation between M^* and τ^*. At any point x (Fig. 4), we have:

$$\frac{M}{EI} = \frac{d^2y}{dx^2}$$

and with $E = 2{,}000{,}000$ tons/metre^2

$$I = \frac{1}{12}Rs^3d\varphi = \frac{1}{12} \,.\, 4{\cdot}5 \,.\, 1{\cdot}5^3d\varphi = 1{\cdot}267\,d\varphi$$

$$\frac{M}{2{,}534{,}000d\varphi} = \frac{d^2y}{dx^2}$$

At the base of the cylinder ($x = 0$), we have $M = M^*$ and

$$\frac{s^2}{u^2}\frac{d^2y}{dx^2} = -2A_2 + 2A_4$$

$$\frac{2{\cdot}25}{0{\cdot}5776}\frac{d^2y}{dx^2} = -3{\cdot}814\tau^*$$

$$\frac{d^2y}{dx^2} = -0{\cdot}981\tau^* \cong \tau^*$$

$$M^* \cong -2{,}534{,}000\tau^*d\varphi \quad \ldots\ldots (8)$$

We shall choose the angle $d\varphi$ so as to have

$$R_4d\varphi = 1 \text{ metre or } d\varphi = \frac{1}{4{\cdot}50} = 0{\cdot}222 \text{ and}$$

$$M^* \simeq -2{,}534{,}000 \,.\, 0{\cdot}222 = -562{,}000\,\tau^*$$

$$\tau^* = -\frac{1{\cdot}78}{10^6}M^* \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

b) Application to Cylindrical Wall *AB* of Spiral Casing under Internal Pressure and End Restraint

The spiral casing can be divided into a horizontal floor *DBC* and a vertical cylinder *AB*, the radius of which is R_1. This cylinder will be heavily reinforced by horizontal rings and its effective modulus of elasticity, when considering tangential stresses, will be:

$$E_1 = \frac{nA_{reinf} + A_{concrete}}{A_{reinf} + A_{concrete}} \,.\, E_{concrete},$$

where A_{reinf} is the area of the reinforcing steel bars and

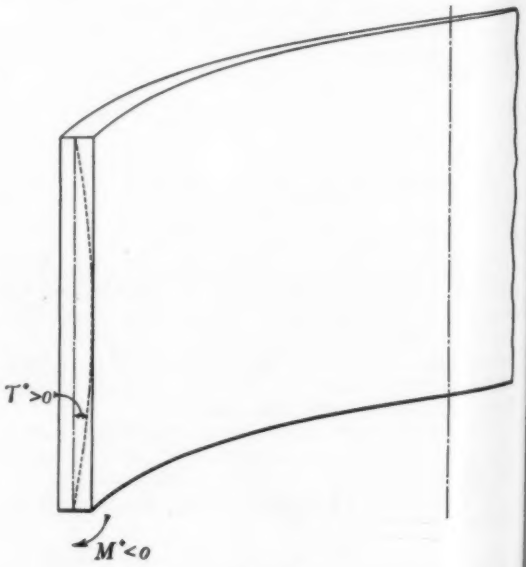


Fig. 4

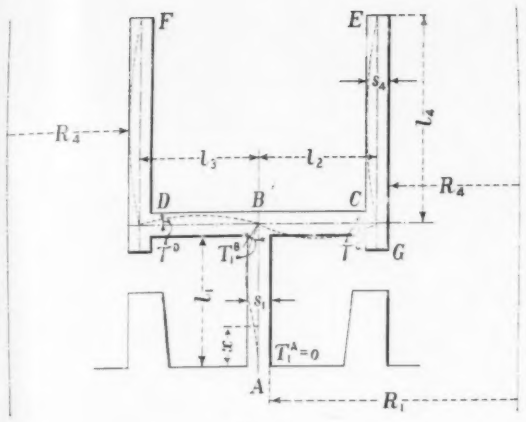


Fig. 5

$A_{concrete}$ the area of the concrete section.

We can put $n \cong 15$ and $\dfrac{A_{reinf}}{A_{reinf} + A_{concrete}} = 0{\cdot}086$

with $E_{concrete} = E = 2{,}000{,}000$ tons/metre^2 we have

$$\frac{E_1}{E} \cong 2{\cdot}2$$

When considering the elastic displacement of the line AB, the modulus of elasticity to be considered will be $E_{concrete}$ as the heavy horizontal reinforcement does not work in this direction.

Strains.

The angular deflections at the ends A and B (Fig. 5) of the cylinder AB are T_1^A and T_1^B. If the foundation of the cylinder is rigid, we write $T_1^A = 0$. The rotation T_1^B of the end B of the cylinder will produce elastic deformations of the slab DBC with angular deflections τ^D and τ^C at the ends D and C. These angular deformations will be transmitted to the two vertical cylinders DF and CE, as all the joints are assumed to be rigid.

The external load is produced by the hydrostatic pressure p inside the spiral casing, which is assumed constant over the whole depth of the casing. In order to solve the problem numerically, we shall consider separately the effects of the horizontal pressure p = constant on the vertical cylinder AB and the effects of the vertical pressure p = constant on the horizontal slab BC. The two effects will then be added.

Equation of deformation of vertical cylinder AB.

The differential equation we have to solve is

$$EI \frac{d^4y}{dx^4} = q = \left(pR_1 - \frac{E_1 y s_1}{R_1} \right) d\varphi$$

$$\text{with } I = \frac{1}{12} s_1^3 R_1 \, d\varphi$$

$$\text{so that finally } \frac{d^4y}{dx^4} = \frac{12p}{Es_1^3} - 12\frac{E_1}{E} \frac{y}{R_1^2 s_1^2} \quad \ldots (10)$$

It can be verified that the integral of this equation is

$$y = \frac{pR_1^2}{E_1 s} + e^{\frac{-u_1 x}{s_1}} \left(A_1 \cos \frac{u_1 x}{s_1} + A_2 \sin \frac{u_1 x}{s_1} \right)$$

$$+ e^{\frac{u_1 x}{s_1}} \left(A_3 \cos \frac{u_1 x}{s_1} + A_4 \sin \frac{u_1 x}{s_1} \right) \ldots\ldots\ldots (11)$$

$$\text{with } u_1^4 = 3\frac{s_1^2}{R_1^2} \cdot \frac{E_1}{E}$$

The boundary conditions for the calculation of the four constants A_1, A_2, A_3, A_4 are

$$\text{For } x = 0 : y = 0, \frac{dy}{dx} = T_1^A$$

$$\text{For } x = l_1 : y = 0, \frac{dy}{dx} = T_1^B$$

We write $\lambda = \dfrac{u_1 l_1}{s_1}$ and calculate y and $\dfrac{dy}{dx}$ for $x = 0$ and $x = l$ out of equations (4) to (7). This finally gives the four equations:

$$A_1 + A_3 = -\frac{pR_1^2}{E_1 s_1}$$

$$-A_1 + A_2 + A_3 + A_4 = \frac{s_1}{u_1} T_1^A$$

$$\frac{pR_1^2}{E_1 s} + A_1 e^{-\lambda} \cos \lambda + A_2 e^{-\lambda} \sin \lambda + A_3 e^{\lambda} \cos \lambda + A_4 e^{\lambda} \sin \lambda = 0$$

$$A_1 e^{-\lambda}(-\sin \lambda - \cos \lambda) + A_2 e^{-\lambda}(\cos \lambda - \sin \lambda) + A_3 e^{\lambda}(-\sin \lambda + \cos \lambda) + A_4 e^{\lambda}(\cos \lambda + \sin \lambda) = \frac{s_1}{u_1} T_1^B$$

Numerical Example.

The hydraulic pressure inside the spiral casing is taken as $p = 20{\cdot}5$ tons/per sq. metre $= 2{\cdot}05$ kg. per sq. cm.

The dimensions of the vertical cylinder AB are: $l_1 = 6{\cdot}40$ metres; $R_1 = 8{\cdot}75$ metres; $s_1 = 0{\cdot}60$ metres with $E = 2{,}000{,}000$ tons/metre^2, $E_1 = 4{,}400{,}000$ tons/metre^2 $\dfrac{E_1}{E} = 2{\cdot}2$.

$$u_1^4 = \frac{3s_1^2}{R_1^2} \frac{E_1}{E} = 0{\cdot}0311, \; u_1 = 0{\cdot}419$$

$$\frac{pR_1^2}{E_1 s_1} = 5{\cdot}94 \cdot 10^{-4} \text{ metres.}$$

$$\lambda = \frac{u_1 l_1}{s_1} = 4{\cdot}47 = 4{\cdot}47 \cdot \frac{180}{\pi} = 256°$$

$\sin \lambda = -0{\cdot}970$ $\quad e^{\lambda} = 87{\cdot}357$

$\cos \lambda = -0{\cdot}242$ $\quad e^{\lambda} = 0{\cdot}0114$

If the foundations are perfectly rigid, then $T_1^A = 0$ and the numerical calculation yields for A_1, A_2, A_3 and A_4 (given in metres):

$$A_1 = -5{\cdot}9 \;.\; 10^{-4} - 1{\cdot}588 \;.\; 10^{-2}\, T_1{}^B$$
$$A_2 = -6{\cdot}21 \;.\; 10^{-4} - 2{\cdot}782 \;.\; 10^{-2}\, T_1{}^B$$
$$A_3 = -0{\cdot}05 \;.\; 10^{-4} + 1{\cdot}588 \;.\; 10^{-2}\, T_1{}^B$$
$$A_4 = 0{\cdot}36 \;.\; 10^{-4} - 0{\cdot}394 \;.\; 10^{-2}\, T_1{}^B$$

(Calculated with slide rule.)

Relations between Moments at A and B, and angular deflections at A and B.

For the vertical cylinder AB, we have $M = EI \dfrac{d^2y}{dx^2}$ with

$$\frac{s_1{}^2}{u_1{}^2}\frac{d^2y}{dx^2} = 2e^{\frac{-u_1 x}{s_1}}\left[A_1 \sin\frac{u_1 x}{s_1} - A_2 \cos\frac{u_1 x}{s_1}\right]$$

$$2e^{\frac{u_1 x}{s_1}}\left[-A_3 \sin\frac{u_1 x}{s_1} + A_4 \cos\frac{u_1 x}{s_1}\right] \ldots\ldots (5).$$

where $I = 0{\cdot}0355\text{m}^4$ (as will be calculated later) and $\lambda = \dfrac{ul_1}{s_1} = 4{\cdot}47$. For $x = 0$ the moment M will be called $M_1{}^A$ and the calculation gives:

$$\frac{M_1{}^A}{EI} = 6{\cdot}42 \;.\; 10^{-4} + 2{\cdot}335 \;.\; 10^{-2}\, T_1{}^B \ldots (12)$$

Similarly for $x = l_1$

$$\frac{M_1{}^B}{EI} = -11{\cdot}45 \;.\; 10^{-4} + 138{\cdot}8 \;.\; 10^{-2}\, T_1{}^B . (13)$$

If we assume $T_1{}^B = 0$, the moment would then be $M_1{}^B = -81{\cdot}5$ metre-tons for a width $R_1 d\varphi$ $= 8{\cdot}75 \;.\; 0{\cdot}228 = 1{\cdot}995$ metre. This moment is the maximum possible value for the bending moment at B for the case when the horizontal floor DBC is infinitely stiff.

The actual value of $M_1{}^B$ can be calculated only as a function of the angular deflection $T_1{}^B$. This angle $T_1{}^B$ is equal to the deflection of the horizontal slab DBC at point B. This deflection has to be calculated and equated to $T_1{}^B$.

c) Application to the Cylindrical Wall *AB* of the Spiral Casing under End Restraint only

The problem we now have to solve is the estimation of the angular deflection τ^{***} produced in the cylinder AB (Fig. 5a), when a moment M^{***} is acting at its upper end B, and when there is no horizontal load acting on the cylinder.

We therefore have $p = 0$ and the equation to be solved is

$$y = e^{\frac{-ux}{s}}\left(A_1 \cos\frac{ux}{s} + A_2 \sin\frac{ux}{s}\right)$$

$$+ e^{\frac{ux}{s}}\left(A_3 \cos\frac{ux}{s} + A_4 \sin\frac{ux}{s}\right) \ldots\ldots (14)$$

the boundary conditions being

$$x = 0,\; y = 0,\; \frac{dy}{dx} = \tau^{***}$$

$$x = l,\; y = 0,\; \frac{dy}{dx} = 0.$$

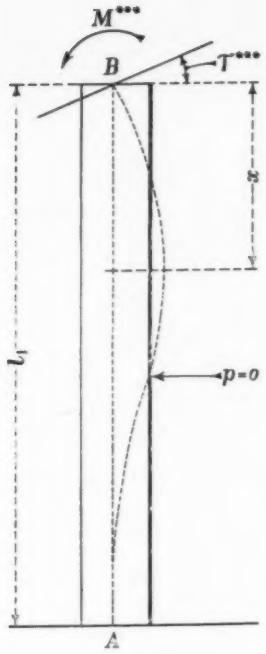


Fig. 5a

These conditions give (in metres):

$$A_1 = -A_3 = \frac{0{\cdot}572}{10^3}\,\tau^{***}$$

$$A^2 = 1{\cdot}740\;\tau^{***}$$

$$A_4 = -\frac{0{\cdot}1515}{10^3}\,\tau^{***}$$

Furthermore, we have ($I = 0{\cdot}0353$ m^4/m):

$$M^{***} = EI\frac{d^2y}{dx^2}$$

and $\dfrac{s^2}{u^2}\dfrac{d^2y}{dx^2} = 2e^{\frac{-ux}{s}}\left[A_1 \sin\dfrac{ux}{s} - A^2 \cos\dfrac{ux}{s}\right]$

$$2e^{\frac{ux}{s}}\left[-A_3 \sin\frac{ux}{s} + A_4 \cos\frac{ux}{s}\right] \ldots\ldots (5)$$

With $s = 0{\cdot}6$m.; $u = 1{\cdot}36$; $\sqrt{s/R} = 1{\cdot}316\sqrt{0{\cdot}6/8{\cdot}75} = 0{\cdot}3444$ and $\dfrac{dy}{dx} = \tau^{***}$. We obtain:

$$M^{***} = -8{\cdot}14 \;.\; 10^4\,\tau^{***} \text{ ton-metres} \ldots . (15)$$

$$\text{or } \tau^{***} = -\frac{1{\cdot}229}{10^5}\,M^{***} \ldots\ldots\ldots\ldots (16)$$

$$\text{or finally } E.\tau^{***}_{m=1} = 24{\cdot}6 \text{ tons/metre}^2.$$

At the other end C of the beam, we have

$$\tau^* = -\frac{3{\cdot}56}{E}\,M^* = -\frac{1{\cdot}78}{10^6}\,M^* \ldots . (17)$$

(To be continued)

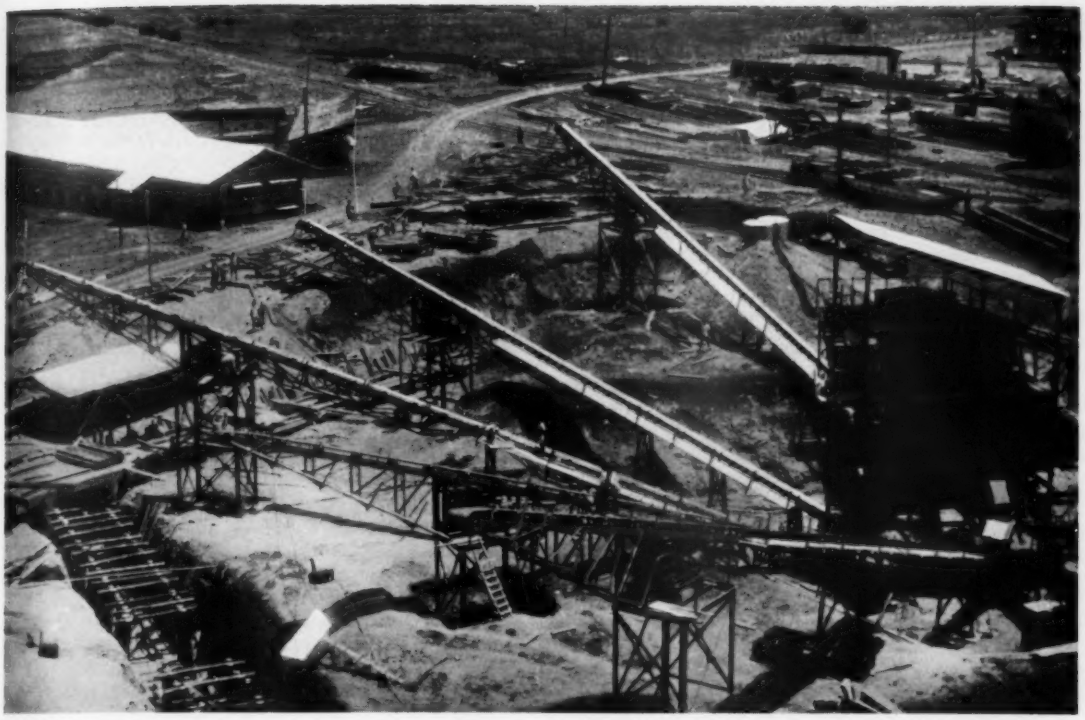


Fig. 1. General view of the Pegson aggregate production plant under construction at Owen Falls

Aggregate Production at Owen Falls

A comprehensive plant for the production of aggregate for this immense scheme is now in operation.

THE Owen Falls scheme, an article on which appeared in our June 1951 issue, is the largest project now in course of construction in Africa. At Jinja, at the source of the White Nile, a dam and power station are being built which will ultimately furnish 150,000 kW to meet the growing needs of industry in Uganda. The ultimate cost is estimated at about £12 million. British and Dutch engineers are already working on the dam, and when it is finished the Owen Falls and the Ripon Falls above them will disappear, as the level of Lake Victoria will be raised by three feet. The dam will control the waters of the Victoria Nile and provide Egypt and the Sudan with a reservoir for all time.

The crushing, screening and storage plant required for the concrete aggregate requirements of the scheme was entrusted to Pegson Limited, of Coalville, Leicestershire, a company of the Mellor Bromley Group, who have been responsible for the design, in collaboration with the Owen Falls Construction Company, and for the manufacture and erection of this interesting plant. The stone being crushed up to the time of writing is amphibolite, which is a close-grained schist, and also a small proportion of river-bed gravel. The amphibolite had a definite tendency to "slabbiness" when crushed, due to the parallel lines of cleavage inherent in the rock. The requirements of the plant were as follows: Total coarse aggregate requirements are 250,000 tons, and in addition 125,000 tons of crushed and natural sand (crushed one-third, natural two-thirds) which are to be produced in approximately two years. The plant capacity for all sizes of coarse aggregate is 125 tons with the ability to produce up to 96 tons per hour of minus $\frac{3}{4}$ in. when required, and 60 tons per hour of sand. The various sizes of aggregate are collected and elevated to the batching plant from the appropriate stock piles by mechanical means.

Because of the remoteness of the site and the limited skilled labour available, the equipment had to be of the finest quality to minimise the probability of breakdowns, and careful consideration had to be given to the type of bearing used in the various machines because of the high atmospheric temperatures, the plant being almost at the equator. The plant had to possess ample reserve capacity in the event of increased tonnage demand in the future. The aggregate sizes required were 3 in., $1\frac{1}{2}$ in., $\frac{3}{4}$ in., $\frac{3}{8}$ in. and $\frac{3}{16}$ in. (sand).

Additional natural sand as distinct from the stone sand produced from the crushers was to be dealt with separately.

The quarried stone is extracted by 1½ cu. yd. shovels and loaded into 4½ cu. yd. dumpers which tip direct into a Pegson-Telsmith 25B gyratory crusher. An alternative feed is by Jubilee skips operating on lines adjacent to the crusher. A feeder is not necessary as this crusher accepts any stone that can be picked up by the 1½ cu. yd. shovels and has a large reserve capacity (350 tons per hour) to deal with fluctuating and intermittent feed. The average feed rate to the crusher is 125 tons per hour. The crusher is situated at a considerable height above ground level, and this has made possible the inclusion of a minor surge pile of crushed stone under the primary crusher and situated inside the foundation walls.

The stone, size minus 8 in., is extracted from this minor pile by means of two Sherwin magnetic feeders and thence to the Pegson-Telsmith 16B primary gyrating crushers which perform the second-stage crushing duties. Provision is made in these feeders for extracting muck from the crushed stone and this is passed to ground by chutes. This feature is only used when muck is present in the stone.

Each of these 16B machines, being of the primary type, can be fed direct from its own large feed storage hopper if desired. The hoppers are fed by the dumpers as required and the rock is controlled at the outlet to the crushers by hanging chains. This arrangement permits the 25B primary to be stopped when particularly good fragmentation is being obtained by blasting in certain parts of the quarry. One or both these 16B crushers can be operated as desired either doing secondary or primary crushing duties. The stone (minus 4½ in.) from the 16B machines passes by way of chutes to the first troughed belt conveyor which is 30 in. wide, 130 ft. centres, and handles up to 220 tons per hour of the minus 4½ in. crushed amphibolite at 200 ft. per min. This and other conveyors were supplied by Hugh Wood & Co. Ltd.

River-bed gravel is fed to this conveyor as required, a receiving hopper being situated above the conveyor, and the gravel is extracted from the hopper at a controlled rate by a Locker's electric vibrating feeder. Approximately 10 per cent. gravel is added to the crushed rock.

The stone and gravel are carried by this inclined conveyor to the screening and surge-bin structure. The first and upper screen is a 12 ft. × 5 ft. Pegson-Telsmith triple-deck machine of the inclined vibratory type. The top deck (scalping deck) rejects all plus 3 in. stone for recrushing into a rejects chute. The second screen is a 12 ft. × 5 ft. double-deck machine.

A five-compartment surge hopper receives and stores aggregate from the screens, sizes 3 — 1½ in., 1½—¾ in., ¾—⅜ in., ⅜—$\frac{3}{16}$ in. and minus $\frac{3}{16}$ in. (sand).

The rejects (8—3 in.) pass from the first screen to a 20 ton capacity storage hopper by chute and a 20 in. wide troughed belt conveyor at 30 ft. centres. Two Locker feeders extract the rejects from the bin and feed by chute into two F. type "Lightning" crushers. These crushers are of the swing-hammer type and were incorporated in the plant to break up the "slabby" rejects preparatory to the final crushing stage. They are designed to run at the rather low speed of 307 r.p.m., thus contributing to maximum manganese life. The product from these crushers is transferred by way of a 24 in. wide, 108 ft. centres curved troughed belt conveyor which delivers the stone to the first conveyor and thence to screens, thus completing the closed circuit.

Fig. 2. "Gyrasphere" and hammermill crushers during erection

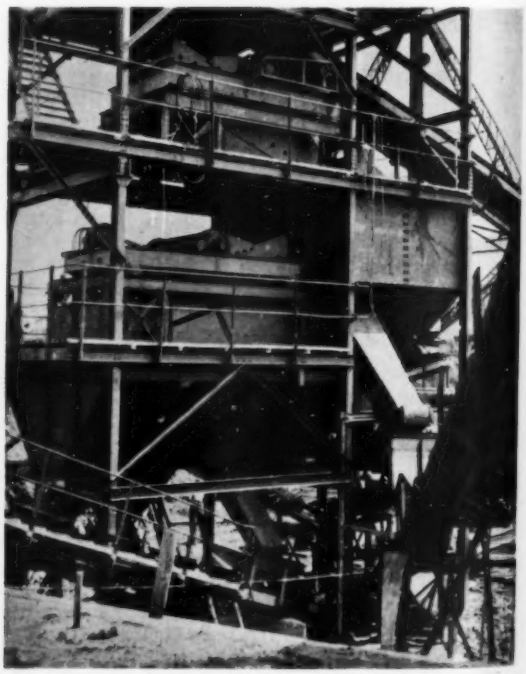


Fig. 3. A view of the screens and surge-bin section of the plant

When increased quantities of the aggregate sizes minus $\frac{3}{4}$ in. are required, a 48 in. Pegson-Telsmith Gyrasphere "fine" crusher is operated. The aggregate sizes 3—$1\frac{1}{2}$ in. and $1\frac{1}{2}$—$\frac{3}{4}$ in. are extracted from either or both appropriate bins by magnetic feeders and carried to the Gyrasphere by an 18 in. troughed belt conveyor. The Gyrasphere reduces the stone to minus $\frac{3}{4}$ in. size, which is deposited on to the 24 in. curved conveyor along with the product of the two Lightning crushers, for rescreening. The Gyrasphere reduces the minus 3 in. stone to minus $\frac{3}{4}$ in. at the rate of 45 tons per hour, thus boosting the quantity of small-size aggregate produced by the previous crushing.

To minimise the stone dust in the aggregate, dust collection is arranged at the points where maximum dust is produced, namely at the Lightnings and the Gyrasphere, where the fine crushing takes place. Air is extracted with the dust in suspension, i.e., immediately it leaves the crushing zones of these machines, and dealt with by a 7 ft. cyclone.

Storage is by the establishment of six major stockpiles each composed of the aggregate gradings specified. The total storage capacity is approximately 14,000 tons, including the natural sand, the stockpiles being approximately 40 ft. high. They are formed by five separate inclined troughed belt conveyors, all being 18 in. wide and running at 150 ft. per min., varying in capacity from 25 to 55 tons per hour according to feed. Each accepts an individual aggregate size from the appropriate surge-bin section and these form the individual stockpiles. The delivery end of these conveyors is cantilevered well out from the conveyor supporting tower, thereby leaving the base of the stockpile clear of obstruction and ensuring easy access for bulldozers or the like for removal of stockpile remnants.

Two 26 in. wide troughed belt conveyors, 240 ft. and 195 ft. centres, are situated beneath the stockpiles in timber tunnels. The aggregate is drawn from any stockpile and introduced to the conveyor by chutes having quadrant-type valves and swivel side plates. There are three outlets to each stockpile, thus ensuring maximum aggregate recovery. Each conveyor will handle 200 tons per hour.

The tunnel conveyors deliver the aggregate to a final inclined troughed belt conveyor which is also 26 in. wide, 258 ft. long, and discharges into the Winget batching plant hoppers at a height of 81 ft., the capacity being 200 tons per hour.

Predetermined proportions of natural sand for the concrete are dealt with independently from the main plant described above. The sand is won from a section of beach on Lake Victoria and is shipped to Jinja by barge, unloaded by grab crane and conveyed to site by lorries. The dry sand is dumped into a water-filled concrete hopper where a pump extracts a solution (30 per cent. sand, 70 per cent. water) and elevates it to a sand cone which delivers 40 cu. yards per hour of washed and graded ($\frac{3}{16}$ in.—100 mesh) dewatered sand, which is then deposited on to a stockpile situated directly above one of the reclaiming tunnel conveyors. The sand is then batch weighed and fed to the concrete mixers along with the main stone aggregate which has previously been batch weighed to meet concrete specification. The dirty water and silt separated by the sand cone is piped to disposal. The natural-sand washing equipment was supplied by William Mosley (Engineers) Ltd., of Feltham, Middlesex.

Drives

All crushers, screens and conveyors are independently driven by totally enclosed surface-cooled motors having tropical windings. Motor control is concentrated at two points. For the primary, secondary and tertiary crushing stage the controls are stationed in an elevated housing commanding a complete view of the plant. The second switchgear point is situated at the top of the main screening section and controls the screens and conveyors. Sequence starting is arranged for. Emergency pushbutton stop switches are arranged at all essential points.

To deal with the heavy lifts when erecting and for subsequent servicing of the plant a 10 ton, 120 ft. derrick covers the large primary and secondary crushers. All high-load bearings of the crushers are lubricated automatically, thereby being independent of the attention of the unskilled native labour.

The plant was put into service in April, 1951, and is satisfactorily fulfilling the duties for which it was we understand that it is satisfactorily fulfilling the duties for which it was designed.

Owen Falls Construction Power Plant

To provide the electrical power for the constructional equipment and for the labour camps on the Owen Falls scheme, Harland & Wolff Limited have supplied 15 diesel alternator sets having a combined output at site of 14,000 kW divided between two generating stations, one at Kampala and the other at Njeru, together with all necessary equipment. Eleven engines are installed at Njeru and four at Kampala. All these engines are arranged for turbo-blower pressure induction.

£343,000 Scheme for Scotland

An order is announced authorising the North of Scotland Hydro-Electric Constructional Scheme providing for the erection in the counties of Dumbarton and Stirling of overhead transmission lines with one line of towers or poles from a transforming station to be erected under the scheme at Strathleven, Dumbarton, to a transforming station also to be erected under the scheme at Kepculloch, Drymen, Stirling. The main purpose of the scheme is to provide a supply of electricity from the 132,000 V transmission lines between Loch Sloy and Windyhill in order to meet the growing electricity requirements of the South-West Scotland Electricity Board in the Dumbarton area. The transmission lines from Strathleven to Kepculloch will augment the supply of electricity in Stirlingshire and other parts of Dumbartonshire. The estimated capital cost of the scheme is £343,000.

Steel Economy

In view of the urgent need for economy in the use of steel the Council of the Reinforced Concrete Association has given renewed consideration to a suggestion that the working stress of 18,000 lb. per sq. in. normally permitted in mild-steel reinforcement complying with B.S. 785 might safely be increased and the quantity used in reinforced-concrete structures thus reduced. Although no yield stress is specified in B.S. 785, recent tests indicate that the yield stress in mild-steel bars of smaller diameter is at least 36,000 lb. per sq. in. This being so the Council is satisfied that a working stress of 20,000 lb. per sq. in. may safely be adopted in bars of $\frac{5}{8}$ in. diameter and less, except in the design of liquid-retaining and other special structures.

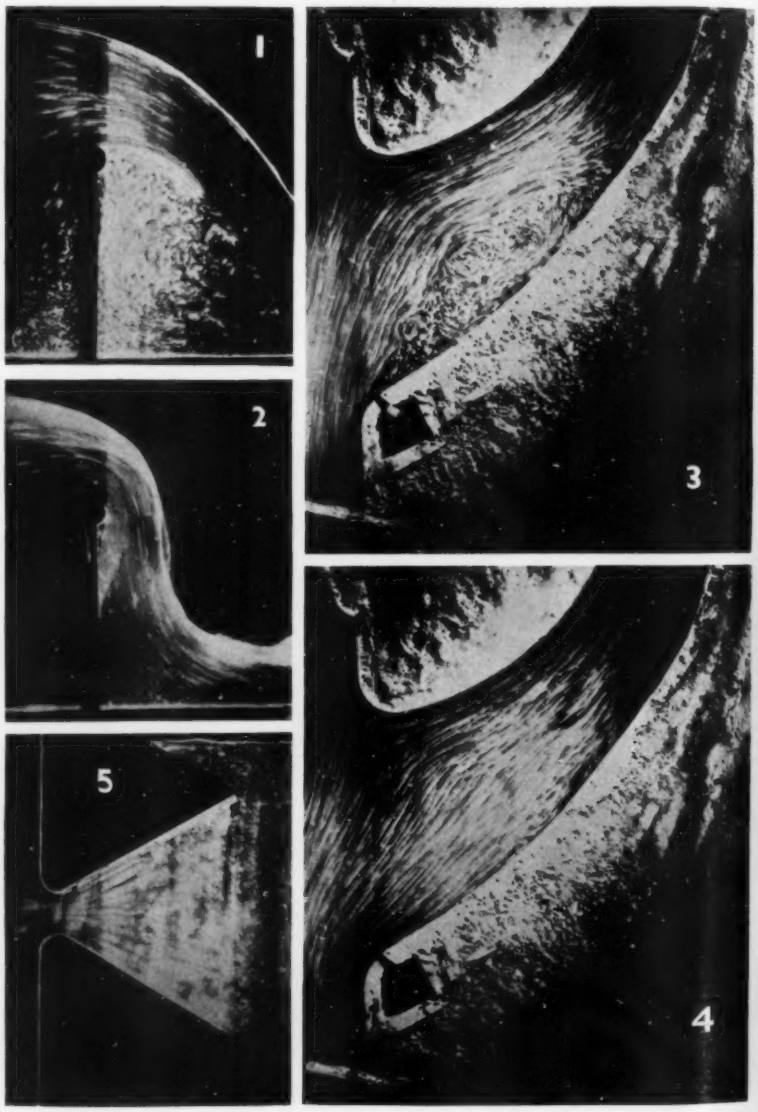
The Influence of the Boundary Layer on Flow Characteristics

We publish a note received from Professor Escande, l'Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique, Toulouse, which was recently presented to l'Académie des Sciences of Paris by Professor Henri Villat.

WHEN fluid flows along a solid boundary, the boundary layer sometimes becomes detached from the surface, thus causing the formation of eddies which restrict the flow and causes losses. This separation of the boundary layer can be greatly reduced by applying suction at the boundary, a method often applied in aerodynamics and frequently mentioned in connection with hydraulics, but which has never, as far as we know, been the subject of experimental demonstration or practical application in the latter field.

From experience, we would expect that most important improvements would result in the functioning of large hydraulic works from the suction of the boundary layer, either by gravity or any other means.

The following examples from our laboratory tests illustrate the way this problem could be tackled:—



Figs. 1—5

In the case of spillways with a small crest radius (Fig. 1) the elimination of boundary-layer separation (Fig. 2) may result in an increased coefficient of discharge of 15 to 20 per cent. over the figure obtaining with the best available profiles

An intake branch (Fig. 4), although limited in length, may function without eddy formation in times of flood, whereas turbulence will appear and silt will accumulate in the absence of suction (Fig. 3).

The output of gates can be increased by means of a slot diffuser functioning without eddy formation (Fig. 5).

Application to Spillway. Fig. 1 shows a spillway with a small crest radius discharging naturally without aeration of the nappe. The turbulence and eddies produced under the nappe can easily be seen and these lead to vibration of the structure. The effect of applying suction at the boundary is illustrated in Fig. 2. The radius of curvature of the nappe is very much reduced, thus leading to larger discharges for the given spillway (about 15 to 20 per cent.) with consequent economy in cost. Turbulence below the nappe is also reduced, thus eliminating vibrations of the structure.

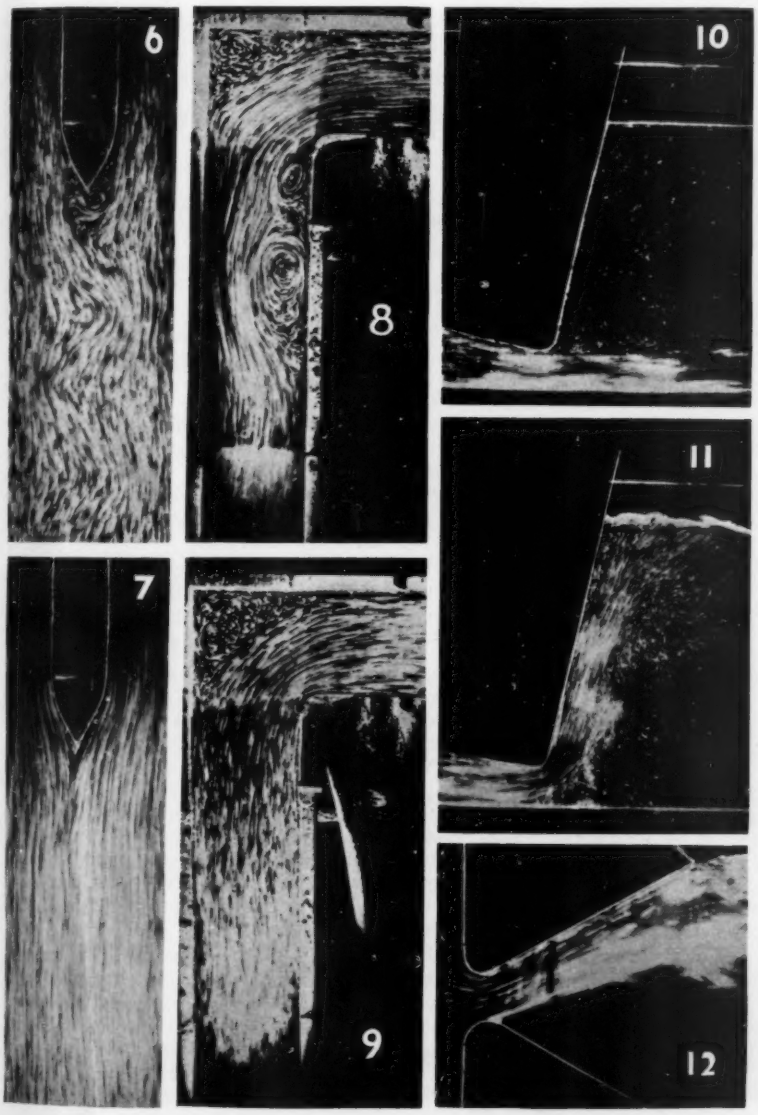
Application to Intake. Fig. 3 shows an intake branch and illustrates clearly the eddies that are produced by separation of the boundary layer. Owing to these eddies the effective width of the intake is reduced by about one-third, and owing to the low water velocity in this region, solids suspended in the water are deposited, thus causing silting of the channel. Fig. 4 illustrates the effect of preventing boundary-layer separation. The channel is now effective over its whole width and silting of the channel will no longer occur.

Diffuser fitted to Valve. Fig. 5, which shows a diffuser fitted to a valve, illustrates the smooth conditions which obtain even with decelerating flow when boundary-layer separation is eliminated.

Flow past a Pier. Fig. 6 shows the flow pattern in the wake of a pier. The vortices which are developed immediately downstream of the pier become detached and create a disturbance in the flow which is in evidence for a considerable distance downstream of the pier. By preventing boundary-layer separation no vortices form and downstream disturbance is eliminated.

Canal Bend. The canal bend illustrated in Figs. 8 and 9 again demonstrates this principle. Elimination of the eddies ensures smoother flow and no reduction in effective width of the channel.

Flow from pipeline into reservoir. Figs. 10 and 11 are a striking example of the complete change of velocity distribution when the boundary layer is prevented from separating. These figures are for a drowned discharge whereas Fig. 12 is for a surface flow.



Figs. 6—12

Eddies in the wake of a pile (Fig. 6) disappear when a double lateral suction is applied in the narrower downstream section (Fig. 7).

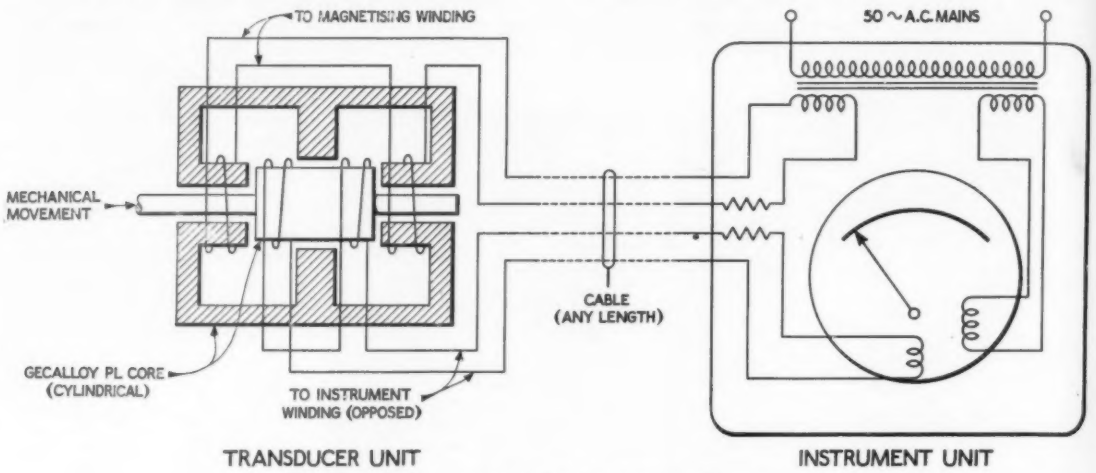
Eddies in a canal bend at right angles (Fig. 8) may similarly be eliminated (Fig. 9).

The natural velocity distribution may be radically altered as Figs. 10 and 11 (submerged flow) and Fig. 12 (surface flow) show.

G.E.C. Remote Indicator

The General Electric Co. Ltd. and Salford Electrical Instruments Limited have developed a new apparatus for measuring mechanical quantities electrically and indicating them at distances up to several miles. The apparatus can be used for the remote indication of liquid levels, pressures, loads and deflections in structures, temperatures, instantaneous pressures caused by explosives, pile drivers and so forth, valve positions, and, in fact, any quantity that can be reduced to a mechanical movement within one-tenth of an inch.

A schematic diagram appears below. The basic principle of the system is that of a change of inductance in a circuit, and the inherent difficulties of earlier change-of-inductance systems, due to magnetic leakage, temperature errors and poor electro-mechanical efficiency have been overcome by the use of an entirely new magnetic powder material "Gecalloy PL." The powder is moulded and used as the magnetic circuit of an electro-mechanical transducer, which can be regarded as an electrical transformer with a core that is moved by the originating mechanical force. The primary winding of the transformer is connected to a.c. mains through a step-down transformer, and the secondary winding is connected to a dynamometer-type indicator.



Circuit diagram of G.E.C. remote indicator

The mechanical force on the movement is transferred to the cylindrical magnetic core in the centre of the unit, and this core can be moved over a total distance of about one-tenth of an inch from a central position inside the secondary windings. The secondary windings are balanced and the current is zero when the core is central, but will increase proportionally as it is displaced. The coils in the converter are connected so that the magnetic flux flows through the core in the same direction as the very small external leakage flux. The secondary windings of the converter are placed on the inside of the unit and are connected in opposition, after balancing so that the voltage induced in each is neutralised when the moving core is exactly central. Alternatively, the core can be displaced a fixed amount and the windings altered so that the full travel of the core from one end of the gap to the other can be used to increase the range of the instrument. If desired, the core in the centre position can be connected to a centre-zero instrument so that differential measurements can be made.

The converter unit is housed in an aluminium-alloy case about 5 in. long, with the operating spindle projecting through the centre of one end. The unit is sealed and is free from temperature error, so that it can be installed in exposed positions and is not prone to mechanical damage. Up to 30 per cent. change of voltage and 10 per cent. change of frequency can be tolerated without the indications being affected. Power consumption is very small and there are no amplifiers to maintain, contacts to keep clean or a multiplicity of moving parts to give trouble. Quantities can easily be summated, multiple indicators can be used, and the inclusion of alarms, servo mechanisms or recorders presents no difficulties.

A four-core cable connects the converter unit to the indicating instrument, which is similar to a standard moving-coil switchboard instrument but is operated by an a.c. electromagnet.

New Centering for Slab Construction

The accompanying illustration shows a new form of falsework centering that Blaw Knox Limited have introduced to speed up the erection of concrete floors in buildings and to reduce the construction costs. "HICO" centering, as it is called, consists of lattice-girder units of various lengths and so light in weight that the sections can easily be handled by one man. The units are furnished with a turnbuckle on the lower boom to enable the whole section to be pre-stressed to maintain the correct level after the load of concrete has been added. No propping or intermediate support is required.

The units weigh only 25 lb. per yard and we understand that it takes less than 40 minutes for two men to erect or dismantle HICO falsework to an equivalent floor area of 1,000 sq. ft. Three sizes of unit are made and by combining different sizes any length of span from 3 ft. to 30 ft., or more, can be bridged. Sagging effects in large spans can be counteracted by tighten-

ing the coupling nuts; this cambers the span, thus compensating the weight of the slab, and if necessary a final correction can be made after the concrete has been poured.

The top boom is formed of a light, pressed channel profile having a bearing width of 6 or 8 in. The centre components are connected by clamps, the transverse forces being accommodated by a groove and tongue. Round steel tie bars are used for the bottom booms and are connected by plugs and sockets adjusted by the turnbuckles.

(left) HICO centering

Abstracts from the World Technical Press

The Châtelot Plant on the Franco-Swiss Frontier

This plant, on which work began in July 1950, is being set up near the spot where the Franco-Swiss stretch of the river Doubs begins, south-west of La Chaux-de-Fonds (Fig. 1). It will be operated by a Franco-Swiss concern ('Société des Forces Motrices du Châtelot," in La Chaux-de-Fonds), in which the French Electricity Authority participates for a half, the other half being covered by the Neuchâtel Canton and three Swiss electricity companies.

The general layout of the installation is shown in Fig. 2 The 74 m. high arched dam will create a reservoir with a useful capacity of 16 M cu. m. (gross capacity 20 M cu. m.). By raising the natural head of 37 m. by 60 m. above the average level, a gross head of 97 m. is provided; with an installed discharge of 40 cu. m. per sec. it will, at full load, be possible to utilise in seven hours the volume of water stored in 24 hours. This gives Châtelot to a large extent the character of a peak-period plant.

The water intake in the reservoir is on the Swiss side of the valley, close to the dam, the water flowing through a 3 km. long penstock 3·70 m. diameter to a steel-lined pressure shaft and to the turbines. The total installed capacity of the two generating sets is 30,000 kW; the average yearly production is assessed at about 100 M kWh of which 57 per cent. is in the October—March and 43 per cent. in the April—September period.

The maximum level of the reservoir will be 716 m. above sea level which gives the reservoir a length of 3·5 km., an average width of 250 m., and an average depth of 50 m.; this storage scheme will involve on both banks of the river the flooding of wide stretches of wooded land which are now being cleared but no inhabited places are affected.

During the construction of the dam the Doubs will be diverted on the French side through a tunnel 150 m. in length and 29 sq. m. in cross-section, with a gradient of 2·25 per cent. and a discharge of 180 cu. m. per sec. The dam itself has a crest 150 m. long, including a side wall combining with the left-bank abutment, and does not differ appreciably from the classical design of arched dams; two

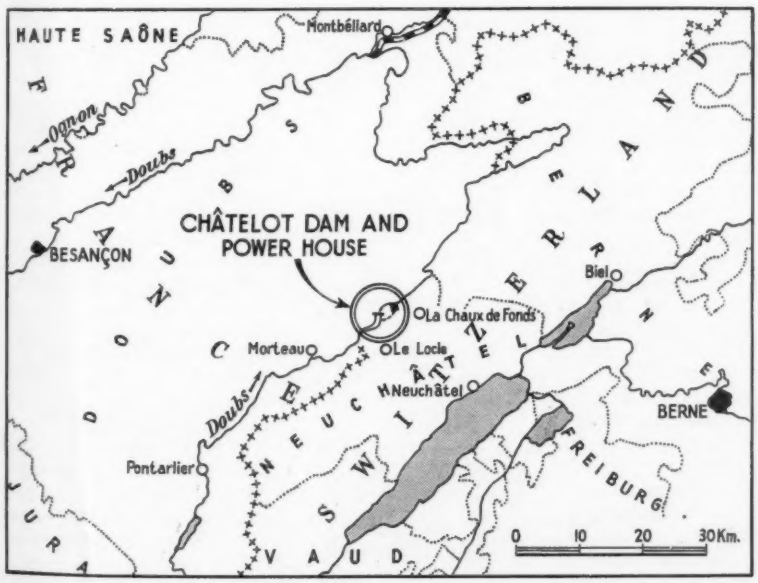


Fig. 1. Map of Châtelot hydro-electric scheme

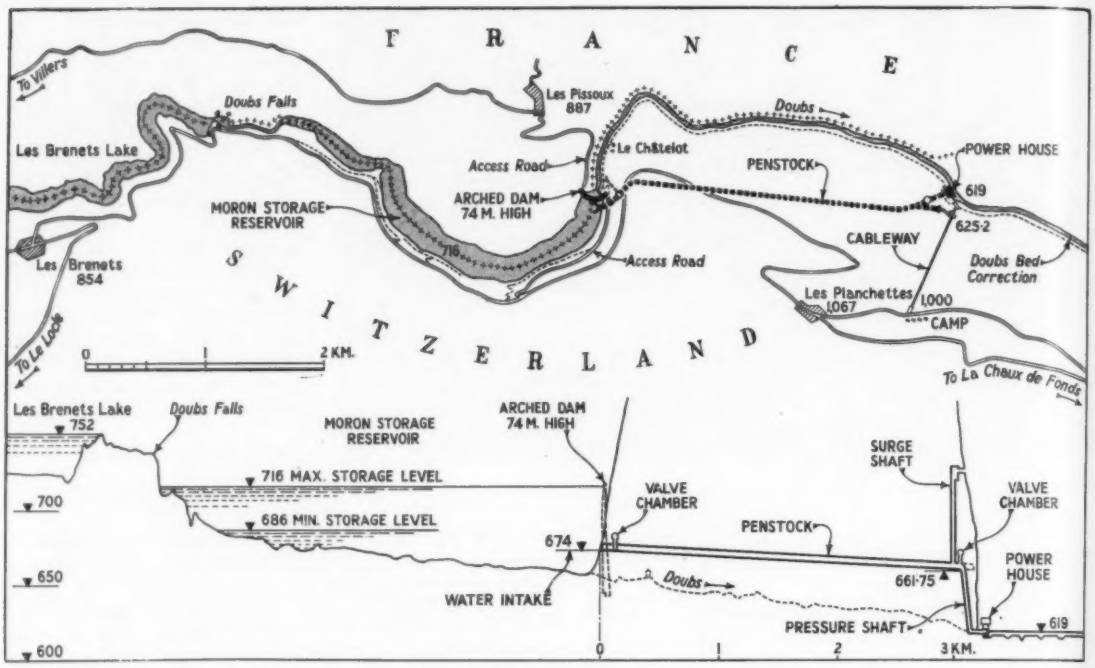


Fig. 2. General layout and profile of Châtelot development

bottom outlets and the overfall section of the crest ensure flood discharge.

The surge chamber (Fig. 3) presents some unusual features. First requirement was to meet all conditions occurring in practice between the highest (97 m.) and the lowest (67 m.) gross head; further, provision had to be made in order to ensure that, when opening the turbine, the water level in the surge chamber would not exceed 30 per cent. of the corresponding net head. The resulting structure is a vertical shaft 10 m. in diameter by 56 m. in height, and there is a throttling arrangement between the penstock and the vertical shaft consisting of a restricted orifice 3·50 sq. m. in cross-section. No bottom chamber is therefore necessary. On the other hand, a top chamber has been provided 5·50 m. above the maximum level of the reservoir with a useful capacity of 640 cu. m. for the water rising from the penstock in case of a sudden load rejection in the turbines. A 4 m. high overflow wall separates the shaft from the top chamber, and the water flows back into the shaft through two outlets 1·20 sq. m. in aggregate cross section. The size of the surge tank has been calculated not only to cope with the usual practice of opening and closing but also to meet cases of opening-closing and closing-opening which may occur in actual operation.

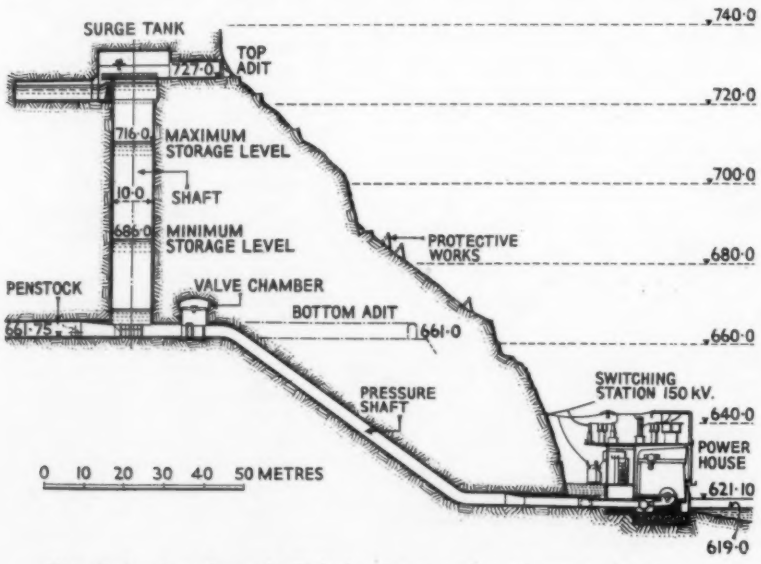


Fig. 3. Section through Châtelot surge tank and power house

The ferro-concrete power house is on the right bank of the Doubs at a level of 621·50 m. so as not to be endangered by floods; it is equipped with two horizontal-shaft generating sets consisting each of a 20,400 kVA three - phase generator driving on either side a clutch-coupled 11,000 h.p. Francis turbine; at low water periods this arrangement enables the set to run with one turbine only so as to cut down operating costs. To each generating set corresponds a 8/60/150 kV three-winding transformer.

Auxiliary accommodation, such as control room, cable chamber, offices, etc., is provided in a separate building downstream from the power house. The main transformers are located between the power house and the mountain, and protected by a ferro-concrete roof; owing to lack of space in the narrow valley, the open-air equipment is fitted on the flat roof of the power house.

Because of the very small gradient of the Doubs between the power house and the spot called Maison Monsieur, 7 km. downstream, its bed has been corrected on a stretch of 1 km. so as to gain a head of about 2·5 m. The corrected bed, half-circular in cross-section, has a gradient of 0·6.

The setting up of this installation involves excavation work to the extent of 120,000 cu. m. in earth, clay, etc., and 100,000 cu. m. in rock; the amount of concrete required is 70,000 cu. m., together with 1,000 metric tons of reinforcing steel. It is expected that the whole plant will be completed at the beginning of 1953. (Contributed by the Swiss concerns Elektro-Watt, Zürich, and Suisélectra, Basle to *Wasser- und Energiewirtschaft*, Vol. 43, April-May 1951, No. 4/5, p. 71, 12 pp., 16 ff.)

Hydro-Electric Schemes in Central Italy

The Società Terni, one of the biggest industrial undertakings in Italy, owns two large hydro-electric schemes, one on the Tiber and its tributaries, and the other on the Vomano on the East Coast. In addition to their high installed capacity (800 MW), the systems are particularly important because of their large storage capacity; when the schemes are fully completed, this will amount to $1{\cdot}2 \times 10^9$ kWh, equal to that of all hydro-electric stations in Switzerland combined. The stations of the second group, as well as most of the first scheme, are characterised by the use of a horizontal pressure gallery followed by a vertical shaft cut in the rock which leads to the underground generating station. This arrangement ensures the minimum length of penstock and the governor response time can thus be shortened so that the system is very suitable for maintaining the frequency of other parts of the grid.

The main storage for the Nera-Velino group (Fig. 1) is provided by two artificial lakes on the Turano and Salto rivers. Two gravity dams, 75 and 104 m.

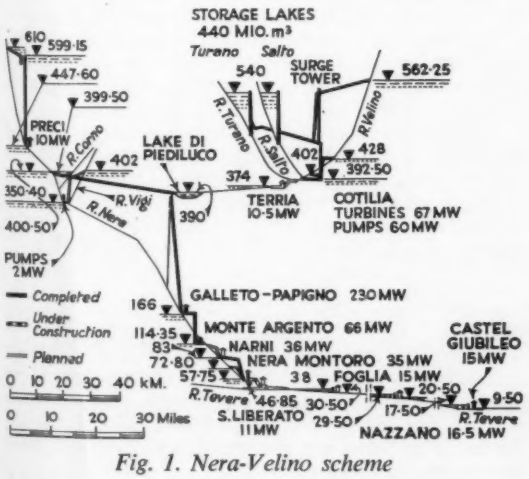


Fig. 1. Nera-Velino scheme

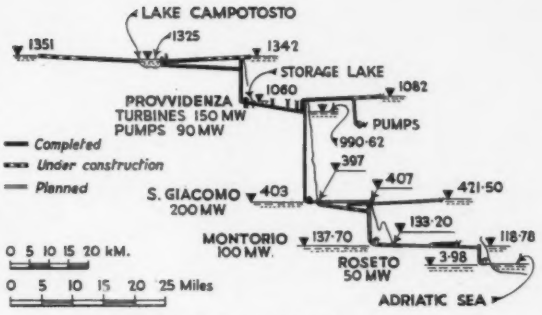


Fig. 2. Vomano scheme

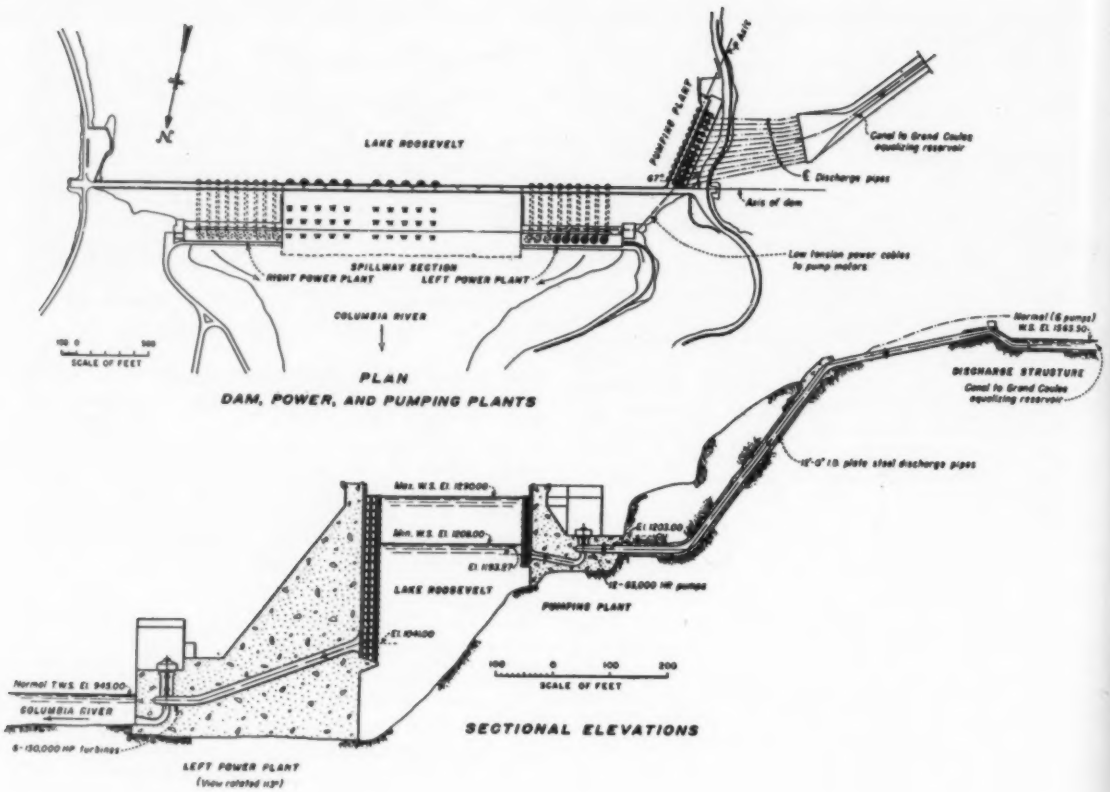
high respectively, store a total of 440×10^6 cu. m. which, after completion of all downstream stations, will represent 450×10^6 kWh. The two lakes are joined by a pressure gallery and discharge into the surge tower of the highest power station. Cotilia, which also utilises the water of the upper Velino. It contains two 30 MW turbo-alternator sets coupled to pumps which are used to store surplus electric energy in the two lakes; their main data are:

Head (m.)	120	145	152
Discharge (cu. m. per sec.)	17.5	14.8	13.3
Speed (r.p.m.)		375	
Power (h.p)	37,600	34,500	32,700
Impeller diameter (m.) ...		2.723	

When not in operation, the pumps run in air, the labyrinth seals being cooled by injecting water.

The Terria station is planned to utilise the head up to the Lago di Piediluco which is used as a balancing basin for the stations further downstream. It also receives the water from the upper Nera after it has passed through the Preci station with an installed capacity of 10,000 kW, while the discharge of the Vigi is raised to the gallery by a 2,000 kW pumping station. The twin plant Galleto-Papigno contains four 50,000 h.p. Francis turbines, in addition to some smaller sets, and is to be extended by a 40 MW turbine. The total discharge of 150 cu. m. per sec. is led through a canal and a free-surface tunnel to the three vertical penstocks of the Monte Argento station which is built underground; a fourth shaft, 5·5 m. diameter, is designed to pass the total flow when the turbine has to be unloaded suddenly. Two vertical shafts provide access for personnel and machinery while the outdoor switching station is situated directly above the turbine room. A further stage is planned to utilise the head to the existing Nera-Montoro station, while the last station on the Nera, S. Liberato, is at present under construction. Further units are planned on the Tiber where the Castel Giubileo station immediately above Rome has just been completed. It utilises 250 cu. m. per sec. at a maximum head of 8·2 m. in three vertical Kaplan turbines with concrete spiral casings.

Four units are planned on the Vomano (Fig. 2), a comparatively short river rising on the Gran Sasso d'Italia. The level of the Campotosto, a natural lake, is being raised by three dams to store 324×10^6 cu. m., corresponding to 826×10^6 kWh for the completed scheme. The area draining into it is being extended by two collectors totalling 42 km. in length. The Provvidenza station, arranged underground and supplied through a vertical penstock 265 m. high, wili



contain three 50,000 kW sets, as well as two pumping units totalling 90,000 kW which have already been described (see issues dated July-Aug. and Sept.-Oct. 1950). The turbine floor is 30 m. below the level of Lake Provvidenza into which the 700 m. long tailrace tunnel discharges. The next stage, S. Giacomo, consists of three 66,000 kW sets and is supplied through a pressure gallery 14·4 km. long which discharges into a vertical penstock 660 m. high and 5 m. diameter. The surge tower also takes in the discharge of several smaller tributaries. Two further stations, of which one is being built and the other is in the design stage, will add 155 MW; the final discharge is taken directly into the Adriatic.

The power is transmitted at 120 to 150 kV and the system is connected to the main 220 kV transmission line running from the hydro-electric schemes in the Alps to Naples, while an extension to Sicily is being planned. All the plant of the Nera-Velino schemes, totalling 345 MW, as well as all the transmission lines, were destroyed during the war and have since been replaced, partly by more efficient equipment. (G. A. Töndury, *Wasser-und Energiewirtschaft*, Vol. 43, No. 9, Sept. 1951, p. 157, 8 pp., 11 ff.)

World's Largest Pump started at Coulee Dam

The first of six of the world's largest pumps, with a 14 ft. impeller weighing 60,000 lb., was started on May 7, 1951, at the Grand Coulee Dam, and has been operating almost continuously since that date, filling as a reservoir a dry, ice-age river bed which will irrigate one million acres of arid land in eastern Washington. Guests of the manufacturers, the Byron Jackson Co., who attended the dedication ceremony on June 14, 1951, saw a torrent of water pouring from a 12 ft. diameter steel pipeline at the rate of 720,000 g.p.m. A second pump was to go into operation by August 1, and the remaining four are in course of erection.

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Contractors' Plant. A leaflet from Ransomes & Rapier Limited gives brief particulars of tilting and non-tilting mixers, truck mixers, roller pan mixers, pan vibrators, self-priming water pumps, excavators and mobile cranes. The items are illustrated, and tables of sizes and capacities are given.

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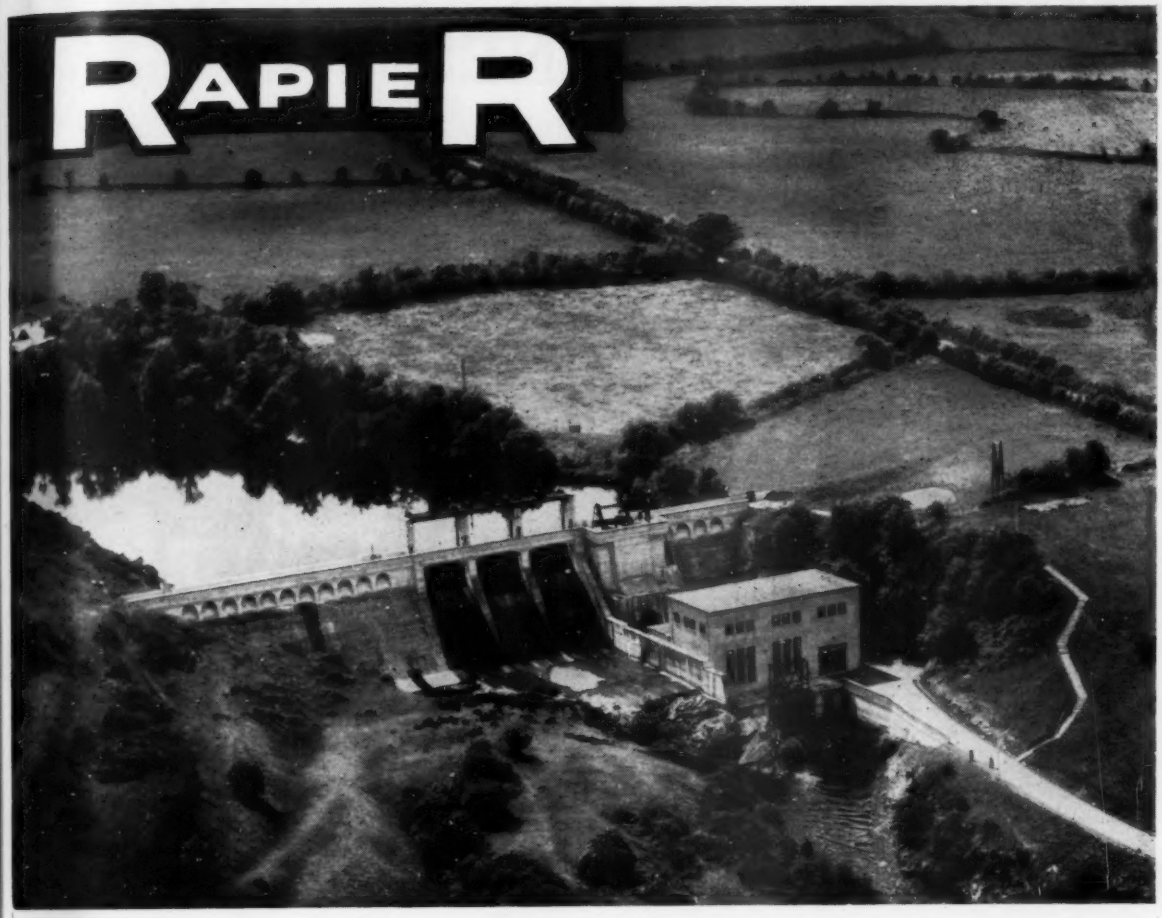

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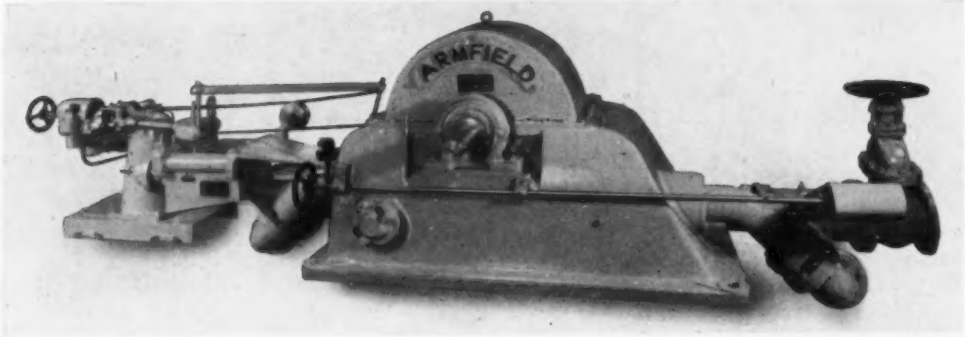

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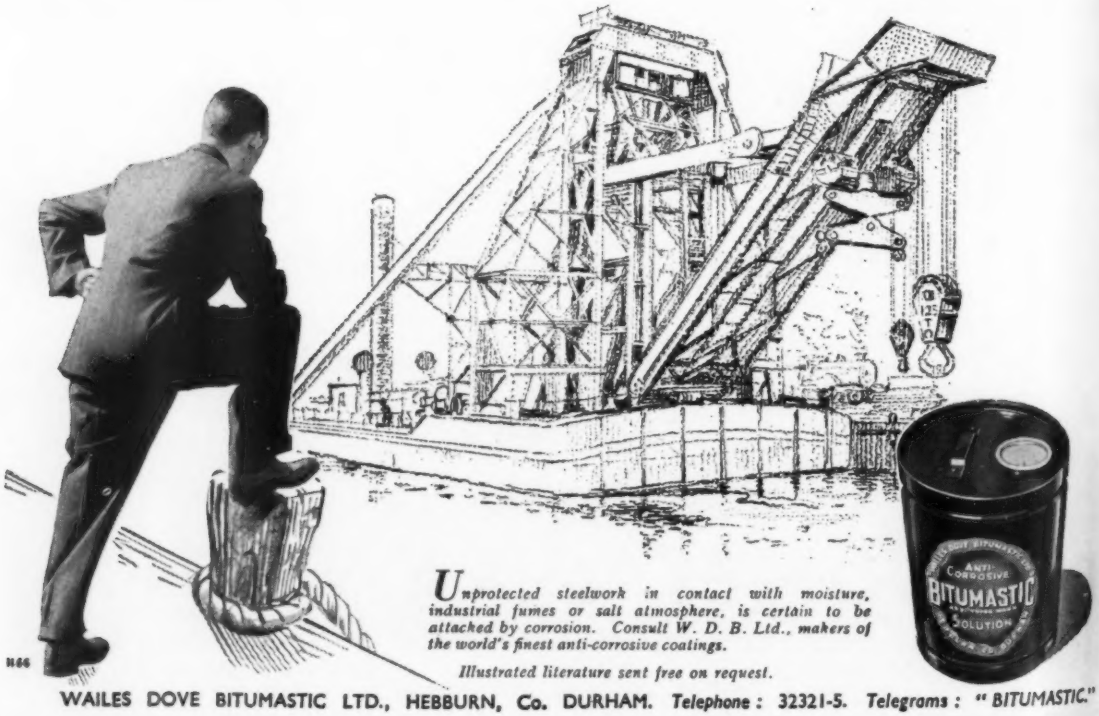

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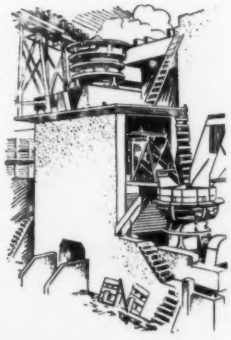

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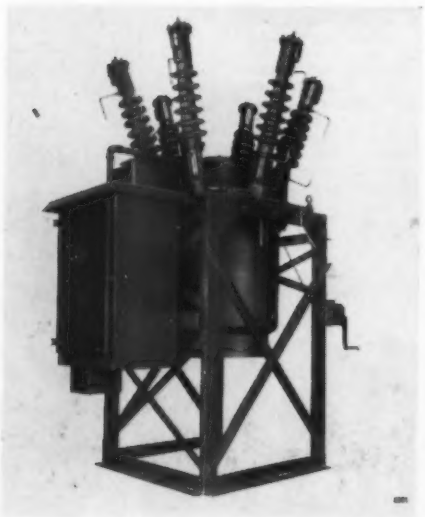

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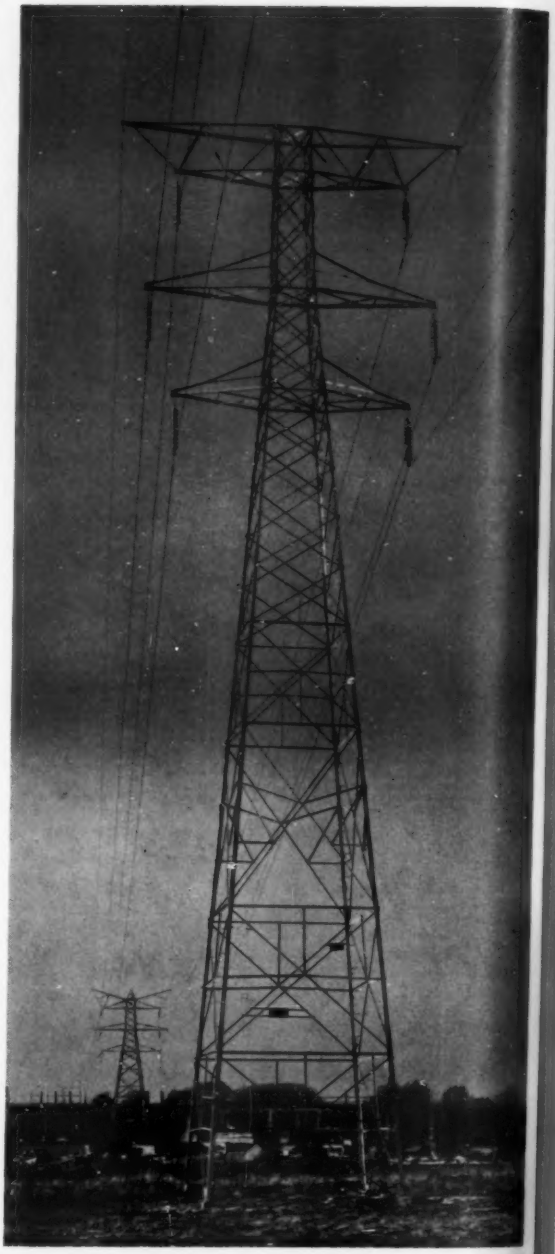

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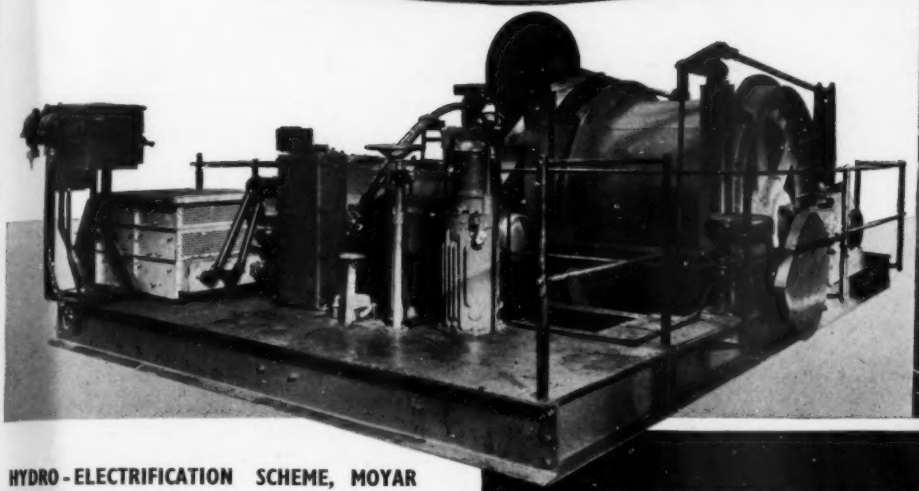

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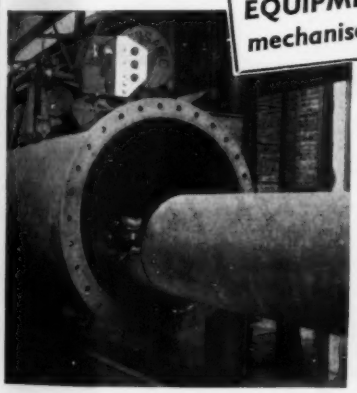

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INDEX TO ADVERTISEMENTS

A
Allgemeine Elektricitats Gesellschaft —
Allmanna Svenska Electriska Aktiebolaget ... ... —
Anderson-Grice Co. Ltd. ... ... —
Armfield Hydraulic Engineering Co. Ltd., The 42
Arrol, Sir Wm. & Co. Ltd. 20
Associated Drilling & Supply Co. (Overseas) Ltd. ... ... —
Ateliers de Constructions Electriques de Charleroi 31
Ateliers de Constructions Mecaniques de Vevey S.A. ... ... —
Atlas Diesel Co. Ltd. ... 10 & 11

B
Balfour, Beatty & Co. Ltd. 6
Bell, Theodore, Ltd. 19
Billington & Newton Ltd. 43
Birkett, T. M. & Sons Ltd. 43
Blackwood, Hodge J. & Co. Ltd. ... —
Blakeborough, J. & Sons Ltd. ... 25
Blaw Knox Ltd. 36
Boving & Co. Ltd. 3
Brady, G. & Co. Ltd. ... ... —
British Insulated Callender's Cables Ltd. 38
British Ropeway Engineering Co. Ltd. 21
British Thomson-Houston Co. Ltd. 33
Brown Boveri & Co. Ltd. 34
Bruce Peebles & Co. Ltd. ... ... —
Butters Bros. & Co. Ltd. ... ... —

C
Cementation Co. Ltd., The 17
Ceretti & Tanfani Ropeway Co. Ltd. 4
Christiani & Nielsen ... ... —
Consolidated Pneumatic Tool Co. Ltd. 39
Costain, Richard Ltd. ... ... —
Crompton Parkinson Ltd. ... ... —

D
Dominion Engineering Co. Ltd. ... 5

E
English Electric Co. Ltd. *Front Cover* & 12
Escher Wyss Ltd. ... ... —

F
Fabbriche Riunite Cemento ... —
Ferguson Pailin Ltd. 44
Ferrum (England) Ltd. ... 22 & 23
Fusarc Ltd. 45

G
Galileo, Officine, di Battaglia Terme 29
General Electric Co. Ltd. 18
Gilbert Gilkes & Gordon Ltd. ... —
Glenfield & Kennedy Ltd. ... ... —

H
Hackbridge & Hewittic Electric Co. Ltd. 7
Harland Engineering Co. Ltd., The —
Henderson, John M. & Co. Ltd. ... —
Henley's, W. T., Telegraph Works Co. Ltd. ... ... —
Holman Bros. Ltd. ... *Inside Back Cover*

K
Karlstads Mekaniska Werkstad ... —

L
Leffel, James & Company, The ... 35

M
Maschinenfabrik Augsburg-Nuernberg A.G. ... ... —
Mechans Ltd. ... ... —
Metropolitan-Vickers Electrical Co. Ltd. ... ... *Back Cover*
Michell Bearings ... ... —
Millars' Machinery Co. Ltd. ... 13
Morgan, S., Smith, Company ... 24
Morris, Herbert Ltd. ... ... —

N
Newport News Shipbuilding & Dry Dock Co. 30
North of Scotland Hydro-Electric Board ... ... —
Nuttall Edmund Sons & Co. (London) Ltd. 28
Nydqvist & Holm Akt. ... ... —

O
Oerlikon Engineering Company ... 14

P
Pegson Ltd. 43
Pirelli-General Cable Works Ltd. ... —
Pyrotenax Ltd. ... ... —

R
Ransomes & Rapier Ltd. 41
Rawlplug Co. Ltd., The 46
Reyrolle, A. & Co. Ltd. *Inside Front Cover*
Riva Costruzioni Meccaniche ... 23

S
Salvi, A., & Co. Ltd. 22
Scarpa & Magnano ... ... —
Smith, Fredk. & Co. ... ... —
Smith, Thos. & Sons (Rodley) Ltd. —
South Durham Steel & Iron Co. Ltd. 32
Standard Telephones & Cables Ltd. 26
Steatite & Porcelain Products Ltd. ... 27

T
Taylor, Tunnicliff & Co. Ltd. ... 16
Tees Side Bridge & Engineering Works Ltd., The 44

V
Vaughan Crane Co. Ltd. ... ... —
Voith, J. M., G.m.b.H. 8

W
Wailes Dove Bitumastic Ltd. ... 42
Watson, Robert & Co. (Constructional Engineers) Ltd. ... ... —
Westinghouse Electric International Company 9
Wild, M. B. & Co. Ltd. 45
Wood, Hugh & Co. Ltd. 15

Y
Yorkshire Electric Transformer Co. Ltd. ... ... —
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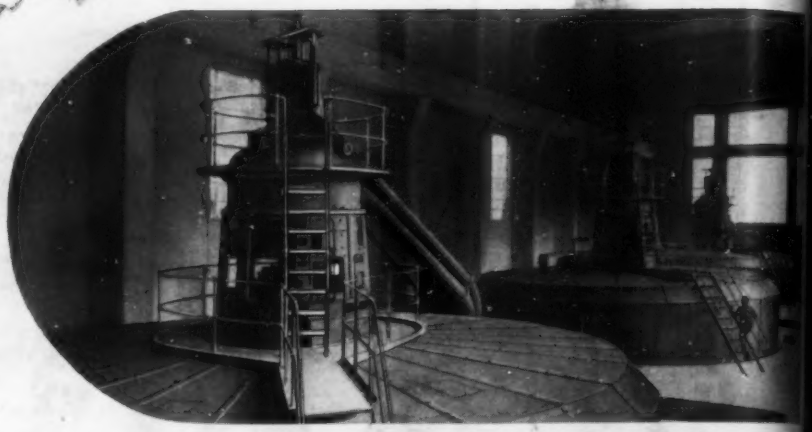
Hydro-Electric Plant

GENERATING

New Zealand

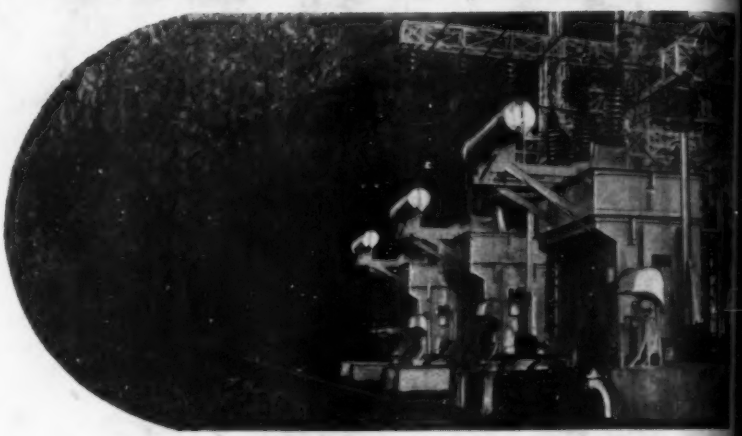
These three Metrovick 33,333 kVA generators are installed in the Karapiro station of the N.Z. Hydro-electric Dept.



TRANSFORMING

India

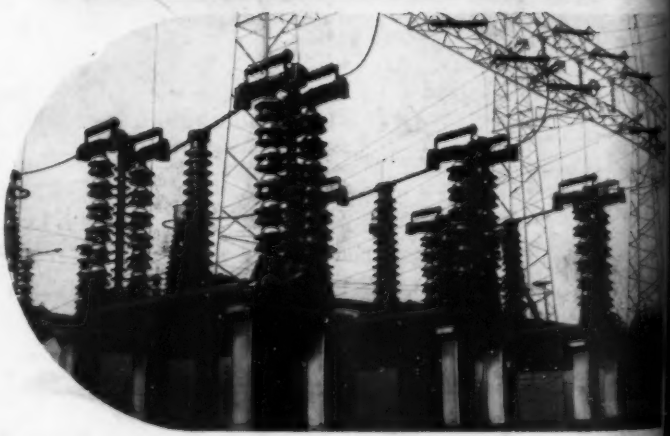
Three of the Metrovick 110 kV 3-phase outdoor transformers at the Pykara hydro-electric station on the Madras Government Irrigation and Power scheme.



SWITCHING

Finland

220 kV 3500 MVA air blast circuit-breakers installed on a Finnish hydro-electric scheme. These are the first British-built 220 kV air blast circuit-breakers for commercial service



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